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ABSTRACT

The Multi-Digit Technologies (MDT) testing technique is discussed as the first major advance in computer assisted testing in several decades. The MDT testing method uses fill-in-the-blank or completion-type questions, with an alphabetized long list of possible responses. An MDT answer sheet is used to record the code number of the answer. For computer scoring, the answer cells are filled in with a soft pencil. Part A of this work gives the background and developmental history of the MDT approach. Part B provides practical instructions on how to use the method, including many helpful hints discovered in the 4 years of development and testing. In Part C, four chapters focus on the educational implications of the MDT techniques. Key topics include: (1) cognitive achievement and retention; (2) mastery training; (3) financial costs and benefits; (4) higher order learning; and (5) research and development. These fundamentals explain how MDT techniques can improve education while lowering costs. The MDT method can allow up to 1,000 alternative responses. The computer's memory of the words that correspond to each label number means vastly improved feedback for students, teachers, administrators, and parents. Appendix 1 gives computer program documentation and installation instructions. Appendix 2 is a warning about unauthorized copying of computer software. Appendix 3 is a list of the MDT answer banks available as of February 1987. (SLD)

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Machine-Scoring of Fill-in-the-Blank Tests

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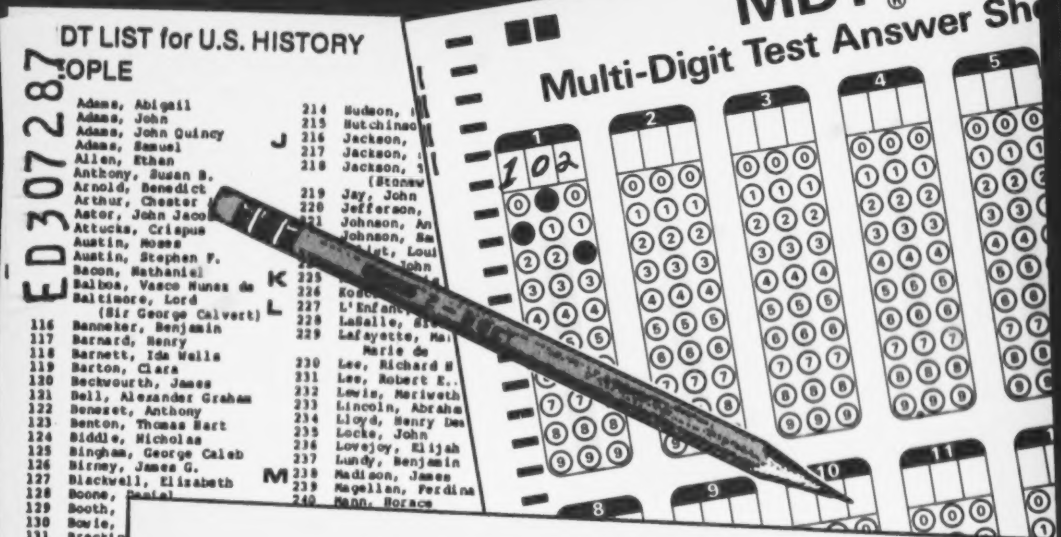

DT LIST for U.S. HISTORY
OPLE

Adams, Abigail
Adams, John
Adams, John Quincy
Adams, Samuel
Allen, Ethan
Anthony, Susan B.
Arnold, Benedict
Arthur, Chester
Astor, John Jaco
Attucks, Crispus
Austin, Moses
Austin, Stephen F.
Bacon, Nathaniel
Balboa, Vasco Nunez de
Baltimore, Lord
(Sir George Calvert)
116 Banneker, Benjamin
117 Barnard, Henry
118 Barnett, Ida Wells
119 Barton, Clara
120 Beckwourth, James
121 Bell, Alexander Graham
122 Benezet, Anthony
123 Benton, Thomas Hart
124 Biddle, Nicholas
125 Bingham, George Caleb
126 Birney, James G.
127 Blackwell, Elizabeth
128 Boone,
129 Booth,
130 Bowie,
131 Breckin
132 Brown,
133 Bruce,
134 Bryan,
135 Buchana
136 Burke,
137 Burr,
C
138 Cabot,
139 Calhoun
140 Cartier
141 Cass,
142 Champla
143 Chase,
144 Chief
145 Clark,
146 Clark,
147 Clay,

214 Hudson,
215 Hutchinso
J
216 Jackson,
217 Jackson,
218 Jackson,
(Stonew
219 Jay, John
220 Jefferson,
221 Johnson, An
Johnson, Sa
K
225
226 Kos
L
227 L'Enfant
228 LaSalle,
229 Lafayette, Ma
Marie de
230 Lee, Richard H
231 Lee, Robert E.
232 Lewis, Meriweth
233 Lincoln, Abraha
234 Lloyd, Henry De
235 Locke, John
236 Lovejoy, Elijah
237 Lundy, Benjamin
M
238 Madison, James
239 Magellan, Ferdina
240 Mann, Horace

TM013274

Sample Questions (Miscellaneous topics)

** Questions 1-3 have word answers. Encode the label numbers from the MDT Answer Bank for U.S. History.

1. The second president of the USA was (blank).
2. Name the explorer who crossed the Lousiana Purchase with Clark.
3. (Analogy) U.S. Grant: Union Army as (blank): Confederate Army.

** Questions 4-6 have precise numeric answers. If you think the number is 43, then mark 043 on your answer sheet.

4. What is the atomic weight of a molecule of H_2O?
5. Solve this equation: $X = 22 + 8 (7 + 3)$.
6. If a population is growing at a rate of two percent per annum, how many years will it take for that population to double?

(Answers are on page iv.

The MDT Innovation:

Machine-Scoring of Fill-in-the-Blank Tests

Paul S. Anderson, Ph.D.
Associate Professor of Geography
Illinois State University
Normal, Illinois 61761

MULTI-DIGIT Technologies Corporation
Normal, Illinois

Answers to Questions on Front Cover

No. 1	102	Adams, John
No. 2	232	Lewis, Meriwether
No. 3	231	Lee, Robert E.
No. 4	018	(Note: These are numerical responses
No. 5	102	and they are independent from any
No. 6	035	word responses on an Answer Bank.)

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Dedication

TO
Lily, Merle, Sarah, Simon,
all other students
and their teachers

Acknowledgments

A large debt is owed to others who have directly contributed to this book and the development of the MDT multi-digit testing. A covey of secretarial staff has had a hand in some part of this project. Patsy Ross, Susan Oross, Nancy Cook, Mindy Turner, Jo Shaffer and Joellyn Parry probably logged in the most hours. Skillful computer programming was done by Waldir Saliba, Shane Steinberg, James Schoner, David Denney, Nora Jones and Tom Scheibel. James T. (J.T.) Madore assisted masterfully with initial text editing, and Michael Ferro, Jr., collaborated on the first promotional efforts. Recent project coordination has been by Paula Schildt.

The contributions of Illinois State University (ISU) have been multi-faceted, as mentioned in Chapters Two and Three. My sincere thanks to all students who participated in the pilot stages and who willingly offered their comments and suggestions about long-list testing. I am also especially grateful to the faculty who took a serious look at the project in the initial years. Of special note were the individual endeavors of Michael Sublett (Chairperson of the Department of Geography-Geology) who nurtured my efforts, Edward Hines (Director of the Center for Higher Education) who offered sage advise and encouragement, and Eileen Kanzler (Instructor at University High School, a laboratory school of ISU) who wholeheartedly became involved in early research activities. Other cooperation and assistance came from numerous administrative units on campus, including various deans, the Measurement and Evaluation Service (directed by Elizabeth Harris) and the Laboratory Schools (supervised by Dennis Kelly).

The "Inventure" Technology Commercialization Center (TCC) at ISU provided major funding from the Illinois

Department of Commerce and Community Affairs (IDCCA) for the research and development work in 1985 and 1986. Other major financial support came from the Department of Geography-Geology and two grants by Colonial Ice Cream, Inc. of St. Charles, Illinois. Furthermore, the Multi-Digit Technologies (MDT) Corporation invested heavily in personnel and funds to create this distinctive addition to educational testing. Timely encouragement and cooperation were also received from National Computer Systems (NCS) and Peripheral Dynamics Inc. (PDI), manufacturers of sheet and card scanners, respectively.

Last, but not least, I acknowledge the contribution via deprivation of my family. Lily, Merle, Sarah and Simon (ages eleven to two) missed out on vacations and other activities because "Daddy is working." My wife, Noeli, not only missed out on those things, but also worked hard to keep our home and family budget intact. She has been a sounding board to whom I brought my projects and problems. Her belief in the educational value of MDT multi-digit testing has never faultered. She encouraged me to keep working to make the MDT innovation available to others even when everything would have been so much easier to limit it to local use.

Although I alone am responsible for any errors or omissions, these people and many others contributed in meaningful ways to make a reality of this book and the MDT testing innovation. Thank you all.

Paul S. Anderson
January 1987

Preface

Just like a "new kid in class" or a "new game in town", there is now a "new testing method in school". The MDT innovation cannot be ignored. It enhances the options for improving education through available technology with substantial financial savings. These issues are all discussed in this book.

Is the MDT multi-digit technique really an innovation? Definitely "Yes". Previous attempts at long-list testing never had more than one hundred terms or a computer program to keep each label number separate (see Section 8.2). The MDT method can have up to one thousand alternative responses. The computer's "memory" of the words that correspond to each label number means vastly improved feedback for students, teachers, administrators and parents. The MDT long-list method of testing is distinct. It fills a highly useful niche.

Part A (Chapters 1-3) gives important introductory and background information. The operational matters in Part B (Chapters 4-7) show how easily educators can obtain the unqiue advantages of MDT testing. Part C (Chapters 8-12) focuses on fundamental educational issues and includes a review of publications relevant to this style of eduactional testing.

This preface is the last page written in this book that summarizes over four years of research and development. The MDT innovation is much more than a book. It is computer software and machine-scored answer sheets. It is a tool for educational reform by helping educators utilize technology to obtain better working conditions. It is a technique to improve student learning and thereby benefit society.

The "new kid in class" is not a bully or trouble maker. Rather, the MDT innovation is more like a newly arrived, intelligent, attractive, well behaved student that enhances the classroom. Although unknown at first, she (or he) will be found to be a true and valuable friend once she is introduced. May this book be your introduction to the MDT innovation.

Table of Contents

The MDT Innovation: Machine Scoring of Fill-in-the-Blank Tests

Acknowledgments vii

Preface ix

Table of Figures xix

PART A: INTRODUCTION AND BACKGROUND OF THE MDT INNOVATION 1

CHAPTER ONE: THREE INTRODUCTIONS 3
- 1.1 First Introduction: A True Short Story 3
- 1.2 Second Introduction: Demonstration Test 8
- 1.3 Third Introduction: Concise Statements About MDT 15
- 1.4 Conclusion 19

CHAPTER TWO: ORIGINS OF THE MDT METHOD (1982-1983) 21
- 2.1 Background For Innovation 21
- 2.2 An Operational Prototype 23
- 2.3 The First Multi-Digit Test 26
- 2.4 Conclusion 28

CHAPTER THREE: THE PIONEER EXPERIENCES (1983-1986) 29
- 3.1 The Pioneer Users 29
- 3.2 Student Attitudes About The MDT Method 33
- 3.3 Commercial Availability And Dissemination Beyond ISU 34
- 3.4 Dissemination And Growth 35
- 3.5 Conclusion To Part A 37

PART B:
OPERATIONAL AND ADMINISTRATIVE ISSUES 39

CHAPTER FOUR: HARDWARE AND SOFTWARE COMPONENTS 43
- **4.1 Computers** 43
  - 4.1.1 Mainframe Computers 43
  - 4.1.2 Minicomputers 44
  - 4.1.3 Microcomputers 44
    - 4.1.3.1 IBM-PC and compatibles 44
    - 4.1.3.2 Apple computers 44
    - 4.1.3.3 Other microcomputers 45
- **4.2 Optical Mark Readers (OMRs = Scanners)** 45
- **4.3 Computer Software** 46
  - 4.3.1 Test Scoring 47
    - 4.3.1.1 Mainframe computer programs 47
    - 4.3.1.2 Microcomputer programs 48
  - 4.3.2 List Making Programs 49
  - 4.3.3 MDT Grade Book 50
  - 4.3.4 Upgrades and Enhancements 50
- **4.4 Optional Manual Scoring Techniques** 50
- **4.5 Conclusion** 52

CHAPTER FIVE: PRELIMINARY PREPARATIONS FOR GIVING AN MDT TEST 55
- **5.1 Necessary Materials** 55
- **5.2 Selecting The Answer Sheet Or Card** 55
- **5.3 Obtaining Long Lists By Purchase, Customizing Or Manual Means** 56
  - 5.3.1 Preprinted Lists 58
  - 5.3.2 Manual Lists 58
  - 5.3.3 Lists Via MDT List Maker 58
- **5.4 Generating An Entirely New List** 59
- **5.5 Number Of Terms On A List** 62
- **5.6 Numbering The Terms** 63
  - 5.6.1 Reserved Numbers 000-010 and 999 63
  - 5.6.2 Reserved Numbers 011-099 63
- **5.7 Actual Numerical Answers** 64

5.8 Other Characteristics Of Lists 65
  5.8.1 Capital Letters 65
  5.8.2 One List for Many Tests 65
  5.8.3 Plastic Page Protectors 67
  5.8.4 Alphabetizing the List 67
  5.8.5 Ambiguous Answers 67
  5.8.6 Two or More Versions of the Same Lists 68
5.9 Making Multiple Copies Of Long Lists 69
  5.9.1 Deterioration of Copy Quality 69
  5.9.2 Copies Too Small or Too Large 69
5.10 Final List Preparation 69
5.11 Supplementary Materials 73
5.12 Conclusion 73

CHAPTER SIX: MDT TEST GENERATION AND QUESTION STYLES 79
6.1 Introduction 79
6.2 Number Of Questions And Range of Scores 79
6.3 Limitations On The Use Of MDT Questions 80
  6.3.1 When Elimination of Alternatives is Important 80
  6.3.2 With Questions such as "Which of the following is not . . . 80
6.4 Additional Ways And Means Of Using MDT Responses 81
  6.4.1 For True and False Questions 81
  6.4.2 For Multiple Choice Questions 81
  6.4.3 For Definition Type Questions 82
  6.4.4 For Numeric Responses 82
  6.4.5 For Several Short but Distinctive Lists 83
6.5 The Use Of Supplementary Pages 83
6.6 Generating Foils For Multiple Choice Exams 84
6.7 Making Banks Of Questions 85
6.8 Subdivisions Or Part Scores 86
6.9 Noncontiguous Parts With Variable Scores 87
6.10 Conclusion 89

CHAPTER SEVEN: IN THE CLASSROOM 91
7.1 Introducing MDT Multi-Digit Testing To Your Students 91
7.2 Basic MDT Rules For All Students (And Their Instructors) 92
7.3 Classroom Situations 94
7.3.1 Seating and Writing Space 94
7.3.2 Passing Out Materials 95
7.3.3 Stray Marks and Darkest Marks Discrimination 95
7.4 Scoring MDT Tests 97
7.5 Results Generated By The Computer 98
7.5.1 The Full Listing or "Dump" 98
7.5.2 Histograms and Statistical Values 100
7.5.3 Difficulty and Discrimination Indices 100
7.5.4 Item Analysis 102
7.5.5 Individual Reports for Each Student 105
7.5.6 Listings for Posting, Grade Book and Rank Order 107
7.6 Computer-Managed Grade Books 109
7.7 The Short Answer SA (Essay) Feature 109
7.8 Instant Scoring 112
7.9 Conclusion 113

PART C:
EDUCATIONAL ISSUES 115

CHAPTER EIGHT: COMPARATIVE RESEARCH ON COGNITIVE ACHIEVEMENT AND RETENTION 117
8.1 Comparisons Of Testing Methods For Cognitive Learning 117
8.1.1 True/False 117
8.1.2 Multiple Choice 118
8.1.3 Matching 119
8.1.4 Fill-In-The-Blank 120

8.2 Previous Attempts To Improve Multiple Choice Situations 121
  8.2.1 Large Matching Methods 121
  8.2.2 Keylist 123
  8.2.3 The Alphabet Method 123
  8.2.4 "Combined Response Areas Per Question" Method 124
  8.2.5 Letters and Numbers 124
  8.2.6 Other Methods and Summary 124
8.3 Previous Comparative Research 125
  8.3.1 Test Formats for Standardized Tests 125
  8.3.2 Test Formats as Research "Treatment" for Retention of Learning 127
  8.3.3 Test Format for Consolidation of Learning 128
  8.3.4 Comments on Previous Studies 130
8.4 Research With The MDT MULTI-DIGIT. Test 130
8.5 Comparison Of Cognitive Retention From Three Testing Methods: Fill-In-The-Blank, Multiple Choice And MULTI-DIGIT Test (MDT) 132
  8.5.1 Introduction 132
  8.5.2 Method 135
  8.5.3 Post-test Evaluation of Retention 136
  8.5.4 Latin Square/Repeated Measures Analyses 139
  8.5.5 Conclusion 140
8.6 Research At University High School 141
8.7 Conclusion 142

CHAPTER NINE: MDT APPLICATIONS FOR MASTERY LEARNING AND TRAINING 145
9.1 Introduction 145
9.2 Mastery Learning, Competency-Based Education And Professional Qualification Examinations 145
  9.2.1 Introduction 145
  9.2.2 The MULTI-DIGIT Innovation in University and Professional Examinations 146

9.3 MDT Method In Entrance Level Testing 147
9.4 Applications Of The MDT Innovation 149
    9.4.1 Elementary Schools 149
    9.4.2 Junior High Schools 150
    9.4.3 Secondary Schools 150
    9.4.4 Training Courses 151
    9.4.5 University Levels and Above 152
9.5 Conclusion 152

CHAPTER TEN: TIME AND FINANCIAL COSTS AND BENEFITS OF THE MDT INNOVATION 153
10.1 Introduction 153
10.2 Preliminary Issues: Hardware And Software Costs 154
    10.2.1 A Computer 154
    10.2.2 Optical Scanners 154
    10.2.3 Software 155
    10.2.4 Summary of Hardware and Software Costs and Benefits 155
10.3 Operational Costs And Benefits 155
    10.3.1 Answer Forms 155
    10.3.2 Lists 156
10.4 Question Quality And Time To Record Answers 156
    10.4.1 The Bank of Possible Answers 156
    10.4.2 Student Speed for Deciding and Recording Answers 157
10.5 Personnel Time 157
    10.5.1 Speed of making a test 158
    10.5.2 Grading the tests 159
    10.5.3 Grade analysis and feedback 160
    10.5.4 System Integration 161
10.6 Additional Benefits 161
10.7 Conclusion 162

CHAPTER ELEVEN: THE MDT INNOVATION AND HIGHER ORDER LEARNING 165
11.1 Introduction 165
11.2 Hierarchies Of Learning 165
11.3 Relationships Between Higher And Lower Order Questions 168

11.4 Higher Order Questions And Guessing 171
11.5 Using Answer Banks With Nominal, Ordinal And Interval Levels Of Measurement 172
11.6 MDT As A Promoter Of Higher Order Learning 173
  11.6.1 Improvement via the Cognitive Base 173
  11.6.2 Task Allocation of Instructors' Time 175
11.7 Conclusion 176

CHAPTER TWELVE: RESEARCH AND DEVELOPMENT: A CONCLUSION THAT OPENS DOORS 179

APPENDIX 1: Program Documentation and Installation Instructions for MDT4 with F1 Answer Sheets 181

APPENDIX 2: "Thou Shalt Not Dupe" by ADAPSO 186

APPENDIX 3: List of MDT Answer Banks 187

BIBLIOGRAPHY 191

INDEX 195

Table of Figures

Figure 1-1 An MDT Long List for World Regional Geography (Actual type size) 5
Figure 1-2 MDT General Purpose Answer Sheet (F1) (Much reduced, front and back) 6
Figure 1-3 MDT Long List Answer Bank for a Demonstration Test 9
Figure 1-4 Supplementary Page: Numbered Map of North America 13
Figure 1-5a MDT Multi-Digit Answer Sheet (F3 with SA Questions) 16
Figure 1-5b MDT Multi-Digit Answer Sheet (continued) 17
Figure 2-1 First Multi-Digit Computer Scored Answer Sheet (Reduced; Black overprint on blue response circles) 25
Figure 2-2 First Long List for a Multi-Digit Test 27
Figure 3-1 First Associated Press Coverage About MDT Methods (May 1985) 36
Figure 4-1 Diagram of Components in the MDT Educational System 40
Figure 4-2 Formats for Manually-scored MDT Answer Sheets 51
Figure 4-3 MDT Hole-Punch for Multi-Digit Testing 53
Figure 5-1 Designs for MDT Answer Grids 57
Figure 5-2 MDT Methods for Numerical Responses 66
Figure 5-3 Generation Deterioration of Copy Legibility 70
Figure 5-4 Common Reduction Sizes for MDT Long-Lists 71
Figure 5-5a Examples of Supplementary Pages: Geography (See also Figure 1-4: Map) 74
Figure 5-5b Examples of Supplementary Pages: Anatomy 75
Figure 5-5c Examples of Supplementary Pages: Mechanics/Hardware 76
Figure 5-5d Examples of Supplementary Pages: Music 77

Figure 6-1 Model for MDT Control Sheet (Mainframe only) 88
Figure 7-1 Printout of All Student Responses ("Dump") 99
Figure 7-2 Histogram of Student Scores 101
Figure 7-3 Difficulty and Validity Report from MDT4 101
Figure 7-4 Item Analysis 103
Figure 7-5 Individual Student Report with Listed Answers 106
Figure 7-6 Printout Reports from Scored Tests 108
Figure 7-7 MDT Grade Book on Microcomputers 110
Figure 7-8 Printout Reports from MDT Grade Book 111
Figure 8-1 Part of a "Long-List": Lists of Geographical Features of World Geography 133
Figure 8-2 An Answer Sheet for the Mulit-Digit Test (Reduced size) 134
Figure 8-3 Tables of Calculated Means by Questions 137
Figure 8-4 Tables of Means in the Latin Square Analysis 138
Figure 11-1 Comparison of Hierarchies of Learning 167
Figure 11-2 Instability Because of Insufficient Base 167

PART A

Introduction and Background of the MDT Innovation

Concerned parents, curious students, practicing teachers, educational administrators and research-oriented university professors all have valid interests in educational testing. Separate, overlapping books about the MDT innovation could have been written for each type of reader. To avoid this overlap, this single book contains sections for specific audiences. You, the reader, will encounter sections that closely relate to your interests. Other sections will be less aligned with your needs. You are encouraged to be selective of the sections that deal with your interests.

Three distinct short introductions to the MDT innovation are presented in Chapter One. The first is a humorous, true story about one student's firsthand experience. The second is a sample test with commentaries to demonstrate the versatility of the MDT testing method. The third is a series of concise academic statements. All three deal with the unique machine-scored, multi-digit long-list ("answer bank") testing method developed by the Multi-Digit Technologies (MDT) Corporation. Apart from tests that require each student to be at a computer terminal, the **MDT testing method is the first major advancement in computer assisted testing in several decades.** This entire book is an explanation of the MDT innovation and how it contributes to the improvement of education.

The developmental background for the MDT advances is recounted in layman's terms in Chapters Two and Three. Originated as a single purpose device for one professor, the multi-digit method has evolved into an entire system applicable to virtually every field of study at almost all educational levels. Comments by various users and students are included in Chapter Three.

The first three chapters constitute Part A. They are probably of general interest to all readers. Part B provides practical, "how-to-do-it" instructions on the use of the MDT method in classrooms. The method is surprisingly simple, but four chapters (Four through Seven) are needed to highlight the abundant, helpful hints acquired during four years of development and pioneer usage. Experienced teachers will quickly see how easily the MDT Educational System is put to use in their classes. Although the writing is specifically for teachers, administrators will understand how to implement it throughout their schools. Students and parents will find Part B to be of minor interest except for the figures and a few sections.

Chapters Eight through Eleven (Part C) focus on the educational implications of the MDT techniques. Although the target audiences are educational administrators and researchers, the issues are of importance to teachers and some other readers. Key topics include cognitive achievement, retention of learning, mastery training, higher order learning and the financial costs and benefits, including saving teachers' time. These topics are the true meat of this book. What really counts is how the MDT innovation can improve education while lowering the costs. These issues are fundamental.

We have only begun to explore the potential of the MDT multi-digit method. The book in your hands sets the stage for the future. Theses, conference papers, grants and publications are forthcoming. Further development of software, hardware and other educational materials are inevitable. But most important are classroom applications for improving education, and this means NOW, not just in the future. All of the necessary components are already operational. As you read this book, know that everything discussed is readily available to meet the needs of practicing teachers, concerned parents, administrators, researchers and students wanting quality education.

Chapter One

Three Introductions

1.1 First Introduction: A True Short Story About MDT Educational Testing

In mid-February 1983, Dr. Joann Rayfield, a professor of History at Illinois State University (ISU), was standing in line at the campus McDonald's. Two male students behind her began talking about a recent test one had taken. She could not help but overhear the following conversation. The students remain anonymous; the names of Alex and Bill simply denote Student A and Student B. The only modifications made are to clarify examples and delete unpublishable expletives. Bill could not see a long list or answer sheet like those in Figures 1-1 and 1-2, but he catches on. This is a true story.

Alex: This guy's exams are a real *!?#!*!#?!*.
Bill: Why? Aren't they multiple choice on computer-scored sheets?

Alex: Yeah, but you really have to **know** the answers.
Bill: (pause) Huh?

Alex: You know, on a regular multiple choice exam there are four to five choices right under each question and you're sure one of them is the right answer. If you don't know the answer you can usually eliminate a couple of choices and then guess.
Bill: How are his questions different?

Alex: This #!*!?+*! has the questions on a couple pages and then a separate page with an alphabetized list of possible answers. You can't guess or eliminate.

Bill: Sort of like matching.

Alex: No. The list of answers is a lot longer than the list of questions. Every answer has a three-digit code number, so he has up to 999 answers. Many couldn't be a reasonable answer, but there are so many you can't narrow it down. You can't eliminate and guess like you can when there are just five choices at a time. It's almost like fill-in-the-blank questions. You really have to be prepared.

Bill: Oh #*$+!

Alex: Yeah, what really bothers me is--what if it spreads?

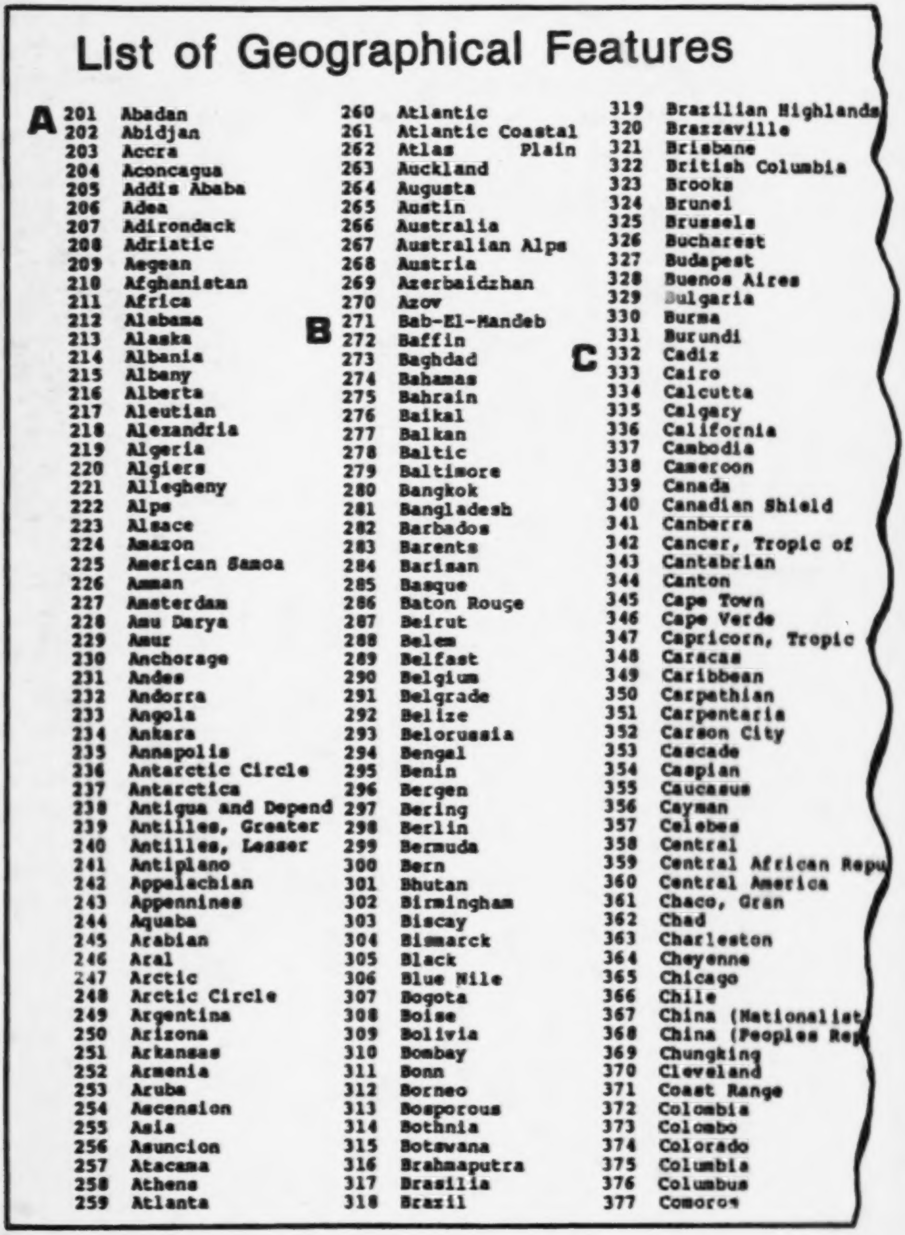
* * * * * * *

What they were talking about was Paul S. Anderson's first examination using the multi-digit method that has evolved into MDT testing. Examples of the answer sheets, response lists and computer printout are shown in numerous figures in this book. Perhaps this true story is the ultimate endorsement for MDT long-list testing. It is a back-handed compliment to the added rigor in this testing method. Alex and Bill are not alone. About half of the several hundred students who have been surveyed in Anderson's World Geography course since 1983 have disliked the MDT method, mainly because the tests are more demanding. But this is not a fault of the testing methods. Instructors (in response to school boards, parents and society) set the standards for a course. The MDT method simply provides additional, more rigorous ways to evaluate learning. If school was supposed to be easy, no tests would be given. Furthermore, all of the other testing methods still remain available for use separately or together with this MDT innovation.

The other half of the surveyed students considered MDT questions as good as or actually preferred over five-choice testing. Many students have given comments similar to the following:

> "I feel that this is a good method of testing. If you have studied and know the material I don't

Figure 1-1 MDT Long List for Geography (Actual type size)



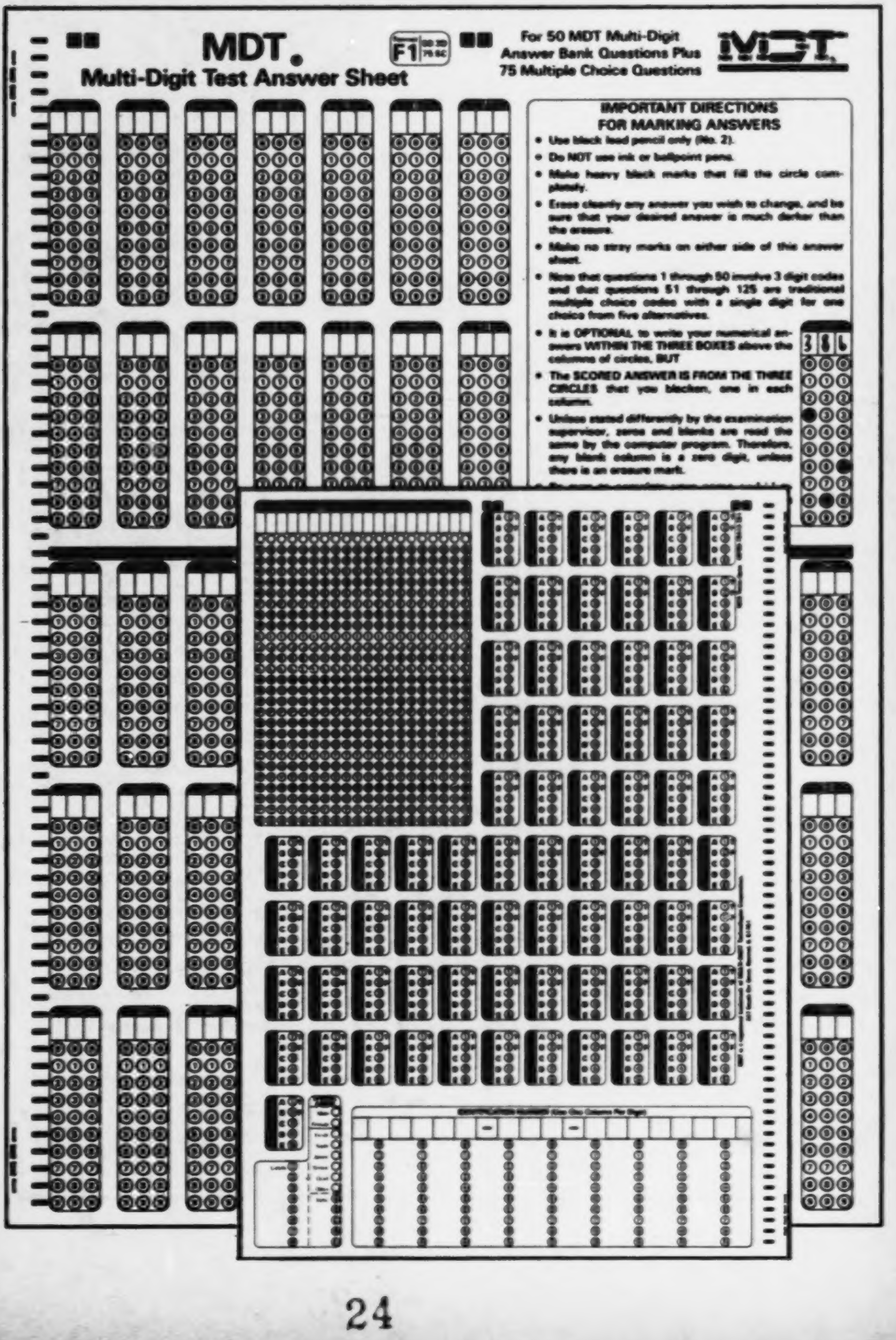
List of Geographical Features

A
201 Abadan
202 Abidjan
203 Accra
204 Aconcagua
205 Addis Ababa
206 Adea
207 Adirondack
208 Adriatic
209 Aegean
210 Afghanistan
211 Africa
212 Alabama
213 Alaska
214 Albania
215 Albany
216 Alberta
217 Aleutian
218 Alexandria
219 Algeria
220 Algiers
221 Allegheny
222 Alps
223 Alsace
224 Amazon
225 American Samoa
226 Amman
227 Amsterdam
228 Amu Darya
229 Amur
230 Anchorage
231 Andes
232 Andorra
233 Angola
234 Ankara
235 Annapolis
236 Antarctic Circle
237 Antarctica
238 Antigua and Depend
239 Antilles, Greater
240 Antilles, Lesser
241 Antiplano
242 Appalachian
243 Appennines
244 Aquaba
245 Arabian
246 Aral
247 Arctic
248 Arctic Circle
249 Argentina
250 Arizona
251 Arkansas
252 Armenia
253 Aruba
254 Ascension
255 Asia
256 Asuncion
257 Atacama
258 Athens
259 Atlanta
260 Atlantic
261 Atlantic Coastal
262 Atlas Plain
263 Auckland
264 Augusta
265 Austin
266 Australia
267 Australian Alps
268 Austria
269 Azerbaidzhan
270 Azov

B
271 Bab-El-Mandeb
272 Baffin
273 Baghdad
274 Bahamas
275 Bahrain
276 Baikal
277 Balkan
278 Baltic
279 Baltimore
280 Bangkok
281 Bangladesh
282 Barbados
283 Barents
284 Barisan
285 Basque
286 Baton Rouge
287 Beirut
288 Belem
289 Belfast
290 Belgium
291 Belgrade
292 Belize
293 Belorussia
294 Bengal
295 Benin
296 Bergen
297 Bering
298 Berlin
299 Bermuda
300 Bern
301 Bhutan
302 Birmingham
303 Biscay
304 Bismarck
305 Black
306 Blue Nile
307 Bogota
308 Boise
309 Bolivia
310 Bombay
311 Bonn
312 Borneo
313 Bosporous
314 Bothnia
315 Botswana
316 Brahmaputra
317 Brasilia
318 Brazil
319 Brazilian Highlands
320 Brazzaville
321 Brisbane
322 British Columbia
323 Brooks
324 Brunei
325 Brussels
326 Bucharest
327 Budapest
328 Buenos Aires
329 Bulgaria
330 Burma
331 Burundi

C
332 Cadiz
333 Cairo
334 Calcutta
335 Calgary
336 California
337 Cambodia
338 Cameroon
339 Canada
340 Canadian Shield
341 Canberra
342 Cancer, Tropic of
343 Cantabrian
344 Canton
345 Cape Town
346 Cape Verde
347 Capricorn, Tropic
348 Caracas
349 Caribbean
350 Carpathian
351 Carpentaria
352 Carson City
353 Cascade
354 Caspian
355 Caucasus
356 Cayman
357 Celebes
358 Central
359 Central African Repu
360 Central America
361 Chaco, Gran
362 Chad
363 Charleston
364 Cheyenne
365 Chicago
366 Chile
367 China (Nationalist
368 China (Peoples Rep
369 Chungking
370 Cleveland
371 Coast Range
372 Colombia
373 Colombo
374 Colorado
375 Columbia
376 Columbus
377 Comoros

Figure 1-2 MDT General Purpose Answer Sheet (F1)
(Much reduced, front and back)



MDT.
Multi-Digit Test Answer Sheet

F1

For 50 MDT Multi-Digit
Answer Bank Questions Plus
75 Multiple Choice Questions

MDT

IMPORTANT DIRECTIONS
FOR MARKING ANSWERS

- Use black lead pencil only (No. 2).
- Do NOT use ink or ballpoint pens.
- Make heavy black marks that fill the circle completely.
- Erase cleanly any answer you wish to change, and be sure that your desired answer is much darker than the erasure.
- Make no stray marks on either side of this answer sheet.
- Note that questions 1 through 50 involve 3 digit codes and that questions 51 through 125 are traditional multiple choice codes with a single digit for one choice from five alternatives.
- It is OPTIONAL to write your numerical answers WITHIN THE THREE BOXES above the columns of circles, BUT
- The SCORED ANSWER IS FROM THE THREE CIRCLES that you blacken, one in each column.
- Unless stated differently by the examination supervisor, zeros and blanks are read the same by the computer program. Therefore, any blank column is a zero digit, unless there is an erasure mark.

think this test should be any harder than another. This really tests what you know, not if you are a good guesser. I like this method." Anon.

"MDT method made me study harder and longer . . . need to know the material . . . eliminates lucky guesses." T.W.

"I like the long-list method since it is more of a challenge. Instead of feeling like you can narrow it down from five, you have to know it out of hundreds." B.J.

". . . you really have to know it and remember it better than with the multiple choice [where] you can more easily recognize the correct answer." J.B.

These comments illustrate several of the problems associated with well-known objective test methods such as multiple choice, true-false and matching. At present, those methods are a mainstay of high school and college testing procedures and are the principal devices used in standardized tests. Except for very carefully prepared exams, objective tests are frequently criticized. Some complaints are that they encourage guessing or rely too much on answer recognition instead of recall. Various critics point out the availability of courses on how to take multiple choice tests. Five-choice tests are also faulted for taking too much of the teacher's time to compose properly. However, objective tests do have their place, plus they are much easier and quicker to grade than essays or the open response fill-in-the-blank tests which require recall.

Many teachers, especially those with numerous courses and high enrollments in high schools and colleges, are forced because of time constraints to employ objective testing. Fill-in-the-blank or essay exams take far too much time to grade. Taking advantage of this situation, good test takers or intelligent students who have not learned the course material succeed in obtaining higher grades by rationally guessing among the five foils. With a multiple choice exam, the teacher is unable to determine concretely and beyond the shadow of a doubt whether or not a student has retained the knowledge and information presented in lectures and textbooks.

Alex, the student in the overheard conversation, would have liked to rely on his guessing and "process of elimination" abilities to succeed on his tests. However, when he encountered the MDT style of questions developed by Anderson, he hit a roadblock. Alex could not guess at the right answer. He confronted a new method designed to eliminate guessing and to find out how much knowledge had been learned.

The MDT answer bank technique essentially offers a "fill-in-the-blank" or completion style test with the cost efficiency of machine-assisted grading. The goal is improvement of education. This MDT method does just that, as discussed throughout this book.

1.2 Second Introduction: Demonstration Test Of The Multi-Digit Testing Method

A fast and easy way to understand the multi-digit testing innovation is to see and use examples of the MDT materials. This section has a few questions for you to answer about American geography and history, plus one (#7) from chemistry. Just follow the step-by-step instructions.

A. The MDT testing method utilizes "fill-in-the-blank" or completion type questions. The first example is very easy:

Question #1: What is the name of the capital city of the United States of America?

You **know** what the answer is and you do not need five choices from which to choose. The MDT method uses an alphabetized long list of possible responses, such as the one provided for this demonstration (see Figure 1-3). For your answer to Question #1, find "Washington, DC" on the list. It and every other possible response has a unique code number. The one for Washington, DC is 785. If it were not on the list, the instructions are to use 999 to indicate that "No reasonable answer is on this list."

An MDT answer sheet or card (see formats in Figures 1-2 and 1-5) is used to record the code number. You can write the numbers in the small boxes. But to be graded by

Figure 1-3 MDT Long List Answer Bank for Demonstration Test

MDT LIST for U.S. HISTORY (selected segments)

A
101 Abolition
102 Abolitionists
103 Actual Representation
104 Adams, Abigail
105 Adams, John
106 Adams, John Quincy
107 Adams, Samuel
108 Alabama
109 Alamo
110 Alaska
111 Algonquins
112 Allen, Ethan
113 Amendment

140 Austin, Moses
141 Austin, Stephen F.

B
142 Bacon's Rebellion
143 Bacon, Nathaniel
144 Balance of Power
145 Balboa, Vasco Nunez de
146 Baltimore, Lord
(Sir George Calvert)
147 Baltimore
148 Bank Notes
149 Bank of the United States
150 Banneker, Benjamin
151 Barbery States
152 Barnard, Henry
153 Barnett, Ida Wells
154 Barton, Clara
155 Bear Flag Republic
156 Beckwourth, James
157 Bell, Alexander Graham
158 Benezet, Anthony
159 Benton, Thomas Hart
160 Bible Commonwealth
161 Bicameral Legislation
162 Biddle, Nicholas

183 British West Indies
184 Brook Farm
185 Brooklyn Heights,
Battle of New York
186 Brown, John
187 Bruce, Blanche K.
188 Bryan, William Jennings
189 Buchanan, James
190 Bull Run
191 Bunker (Breeds) Hill
192 Burke, Edmund
193 Burr, Aaron

C
194 Cabot, John
195 Calhoun, John C.

F
302 Factory System
303 Farming
304 Farragut, David G.
305 Favorable Balance of
Trade
306 Favorite Son
307 Federalism
308 Federalist Party
309 Fillibuster
310 First Continental
Congress
311 Fisk, James, Jr.
312 Five Nations
313 Florida

361 Greenbacks
362 Grenville, George
363 Griffing, Josephine
364 Grimke, Angelina
& Sarah
365 Grist Mill

H
366 Habeas Corpus
367 Hale, Sarah Josepha
368 Halliday, Daniel
369 Hamilton, Alexander
370 Hancock, John
371 Harpers Ferry Raid
372 Harrison, Benjamin
373 Harrison, William H
374 Harte, Bret

J
412 Jay, John
413 Jefferson, Thomas
414 John Brown's Raid
415 Johnson, Andrew
416 Johnson, Samuel
417 Joint Stock Company
418 Joliet, Louis
419 Jones, John Paul
420 Judicial Branch
421 Judicial Review
422 Justice of the Peace

K
423 Kansas
424 Kaskaskia
425 Kentucky
426 Key, Francis Scott
427 King Mountain
428 King Philip's War
429 King Pin (or Lychpin)
Clause
430 Kiowas
431 Kitchen Cabinet
432 Knight of the White
Camellia
433 Know-Nothing
(American Party)
434 Kosciusko, Thaddeus
435 Ku Klux Klan

502 Middle Passage
503 Militia
504 Minnesota
505 Minutemen
506 Missionaries
507 Mississippi
508 Missouri
509 Mohawks
510 Monopoly
511 Monroe, James
512 Montana
513 Montreal, Canada
514 Moody, Lady Deborah
515 Mormons
516 Morse, Samuel F. B.
517 Mott, Lucretia
518 Mugwumps

N
519 Nast, Thomas
520 Nation, Carrie
521 National Road
522 Nationalism
523 Natural Rights
524 Nauvoo

654 Rush, Benjamin
655 Russia

S
656 Sacajawea
657 Sachem
658 Salem
659 Salt Lake City
660 Salutary Neglect
661 Sampson, Deborah
662 San Jacinto
663 Santa Anna
664 Santa Fe Trail
665 Santa Fe
666 Saratoga
667 Savannah
668 Scalawags
669 Schurz, Carl
670 Scott, Dred
671 Scott, Winfield
672 Seasoning
673 Secession
674 Second Continental
Congress
675 Sectionalism
676 Sedition
677 Segregation
678 Self-Governing Colony
679 Self-Reliance
680 Senate

W
780 Walker, David
781 Waltham System
782 War Hawks
783 War of 1812
784 Ward
785 Washington, DC
786 Washington, Booker T.
787 Washington, George
788 Watt, James
789 Weaver, James B.
790 Webster, Daniel
791 Webster, Noah
792 West Indies
793 West Virginia
794 West, Benjamin
795 Wheatley, Phillis
796 Whigs
797 Whiskey Rebellion
798 White Supremacy
799 Whitman, Walt
800 Whitney, Eli
801 Williard, Emma Hart
802 Winnemucca, Sarah
803 Winthrop, John
804 Wisconsin
805 Woolman, John
806 Wounded Knee
807 Writs of Assistance
808 Wyoming
809 XYZ Affair

Y
810 Yeoman
811 Yorktown
812 Young, Brigham

the optical scanner and computer, the small answer cells (circles or rectangles) have to be marked with a soft pencil. The answer for Question #1 is filled in as an example. It could also be recorded on a sheet for manual grading, as discussed in Section 4.4. Easy questions such as #1 could have a low point value and could help identify the really unprepared students.

B. Now that you see how it works, let's try a harder question:

> **Question #2: Name the American President who immediately preceded Abraham Lincoln.**

If you know the answer, you will find it easily on the long list; then mark your answer form. If you don't know who he was, do not try to read the entire long list of responses. It is intentionally long to discourage anyone searching to recognize the answer, especially if this were a real test using a full (not abridged) long list during a class period. After you have completed the demonstration test, you will be told where to find the correct answers.

C. The MDT method requires only what is called the "stem" of the question. The instructor does not need to think up the alternative wrong answers (called "foils" or "distractors").

> **Question #3: Until 1763, Great Britain pursued a policy of (blank) toward her colonies.**

Tough question. Perhaps too tough, but the instructor is responsible, not the the MDT testing method. Maybe the instructor has a special purpose, such as challenging the "A" students. Here the purpose is to compare the MDT multi-digit method with the five-choice method. Could you answer it if the choices were:

> 001 Cloture; 002 Conquered provinces theory; 003 Salutary neglect; 004 Nullifaction; 005 Emancipation.

The answer is even more clear when the foils are poorly chosen. Try these:

> 738 Temperance; 222 Collective bargaining; 675 Sectionalism; 403 Insurrection; 660 Salutary neglect.

Five-choice questions can still be appropriate if recognition (not recall) is sufficient or if all five alternatives are to be pondered. But when recall of discrete answers is desired, the MDT method is clearly superior.

D. Supplemental pages further enhance the versatility of the MDT innovation. Look at the attached map of North America (Figure 1-4) and consider how many hundreds of questions could be easily asked. You are only asked to answer two questions. This method also works very well in teaching subjects such as anatomy (Figure 5-5b) and auto mechanics.

Question #4: Using the attached map of North America, name the river that forms the boundary between states numbered 33 and 62.

Note that none of the terms on the answer list have "modifiers", such as "River" or "State". Therefore, each term could be used in a variety of different contexts. If your answer is not on the list, fill in code number "999".

Question #5: What is the location number on the map (Figure 1-4) that most correctly identifies the position of the Erie Canal?

If you think it is closest to position No. 34 on the map, then your answer code should be 034 on the answer form.

E. Actual numerical values can be the answers. A very simple example is in Question #6. Question #7 is harder.

Question #6: Currently, 50 states comprise the United States. Thirty-

> seven of these states joined the Union after 1787, the year the Constitution was adopted. How many states were there in 1787?

Just figure it out and encode your answer. There is no need for a long list; any three-digit number can be the answer.

Question #7: (Chemistry calculation) How many grams of water (H_2O) are produced by the combustion of 12 grams of free hydrogen (H_2)? (Round to the nearest whole gram.)

Question #7 is much harder, unless you have studied chemistry recently. You could be given five choices, but that would make it easier to guess. Note that the question specifies the unit of measurement and can also indicate (if needed) where a decimal point should be placed.

F. The preceeding question required the application of learning. The MDT multi-digit testing method has many uses beyond the recall of factual knowledge. Consider the case of a U.S. History class that had not specifically seen the statement which follows in Question #8. Here the student must use some of the higher orders of learning to answer a series of questions.

Question #8: What person was the leader of the school of thought expressed in the following statement?

> 'The incorporation of a bank, and the powers assumed by this bill, have not, in my opinion, been delegated to the United States by the Constitution . . . They are not among the powers specially enumerated . . . Nor are they within either of the general phrases, which are the two following: 1) "To lay taxes to provide for the general welfare of the United States." |. . . They

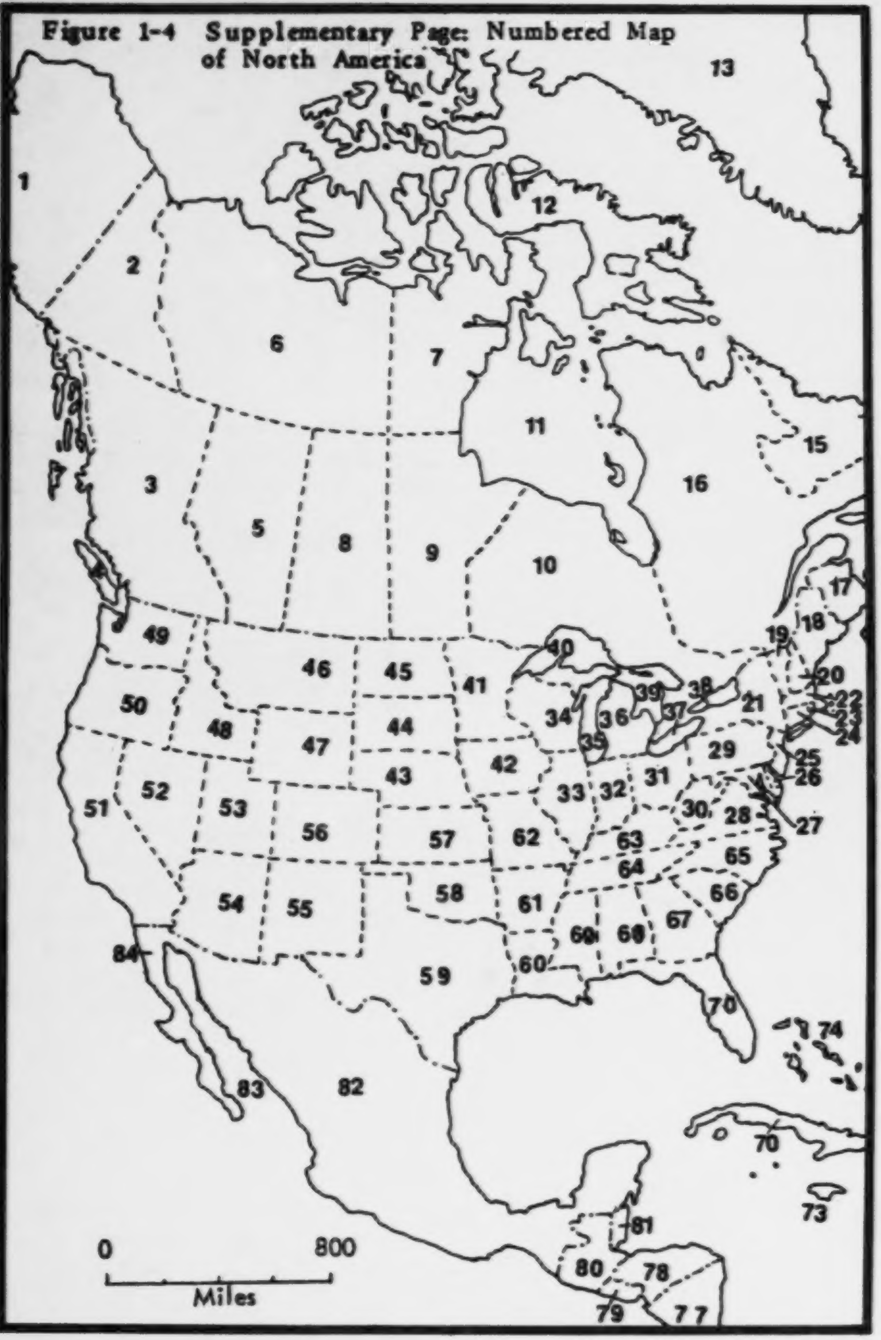


Figure 1-4 Supplementary Page: Numbered Map of North America

13
1
12
2
6
7
11
15
3
16
5
8
9
10
17
18
49
40
19
46
45
41
20
39
38
22
50
34
36
37
21
23
48
47
44
35
24
29
25
42
26
43
31
33
32
51
52
53
30
28
27
56
57
62
63
65
64
54
55
58
61
66
67
69
68
84
60
59
70
74
83
82
70
73
81
0
800
Miles
80
78
79
77

(Congress) are not to do anything they please, to provide for the general welfare, but only to lay taxes for that purpose. 2) . . . "to make all laws necessary and proper for carrying into execution the enumerated powers." But they can all be carried into execution without a bank. A bank, therefore, is not necessary and consequently not authorized by this phrase.'

Question #9: What institution is the object of the criticism in Question 8?

Question #10: Who would have been the chief opponent of this critical view?

Question #11: What political group was most likely to have supported the criticism?

The student must demonstrate understanding of the principles of "reserved" and "delegated powers" of the Constitution and know the basic positions of the parties and spokesmen. These questions require thought based on knowledge, without having big "hints" in five choices.

G. A further innovation by Multi-Digit Technologies Corporation focuses on essay questions. The trademarked "SA" feature facilitates the grade book entry and analysis of student scores for short answers and essays. In normal fashion the student writes the answer and the teacher manually reads and grades it. Then the teacher encodes the number of points earned on the special SA positions on the MDT answer sheet. The scanner and computer can then record and analyze the results plus print reports for the student and teacher. SA questions 101 through 103 illustrate this feature in Figure 1-5.

Question SA 101: Show your calculations for Question #7 asked above. The calculations are worth five additional points, separate from your answer to Question #7.

Question SA 102: Briefly explain the "triangular trade" of Colonial America?

Question SA 103: Please list the "freedoms" or "rights" protected by the First Amendment?

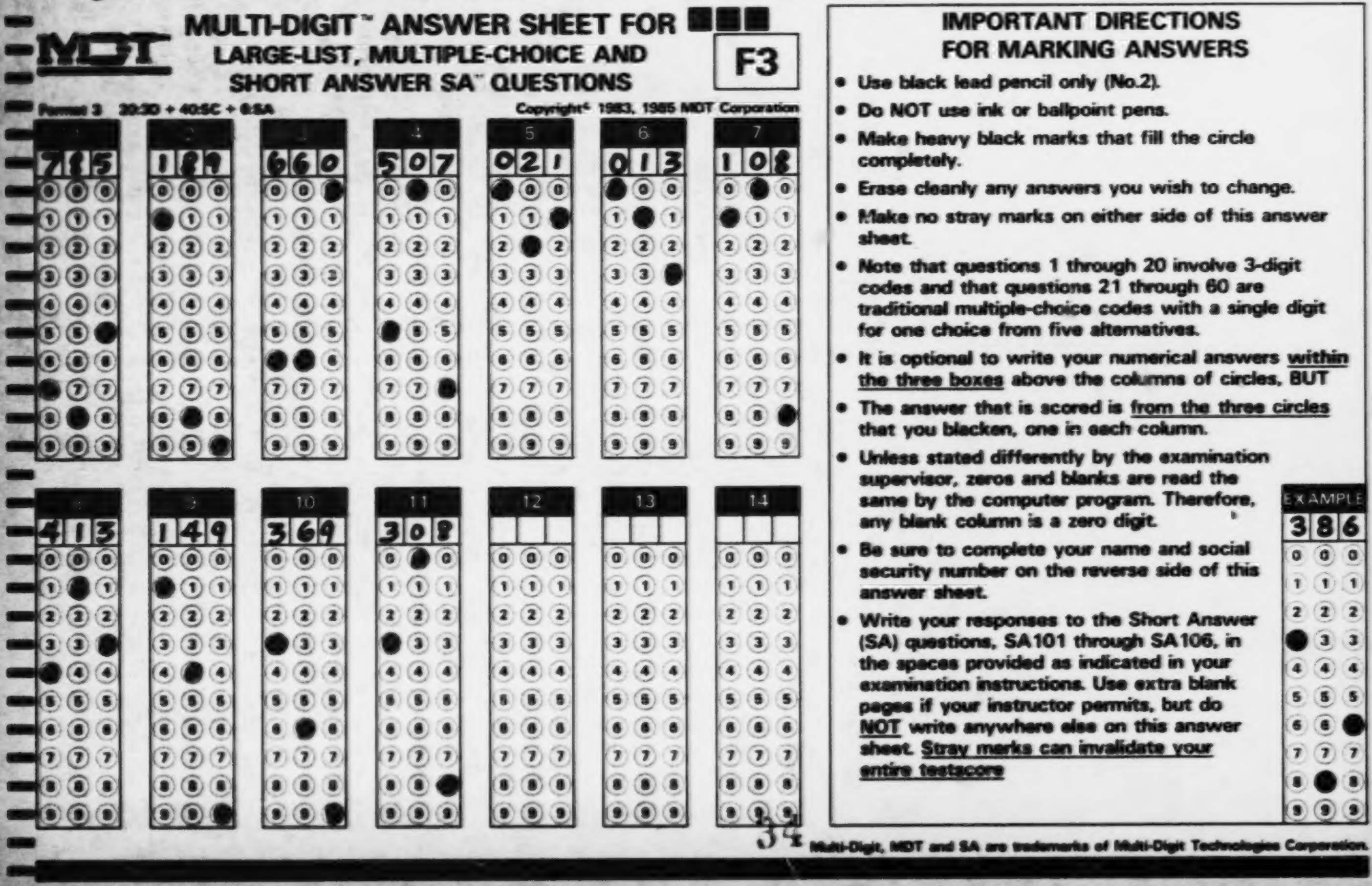
Examples of responses to the above SA questions are shown in Figure 1-5. The answers to the other questions in this demonstration test are also given in that figure. The examples in this demonstration test are certainly not exhaustive. Every discipline has distinctive content that lends itself to further variations of the MDT multi-digit testing innovation. Several of them are discussed in the more technical chapters in Parts B and C.

1.3 Third Introduction: Concise Statements About The MDT Multi-Digit Testing Innovation

The MDT multi-digit testing procedure combines the characteristics and advantages of recall thinking associated with fill-in-the-blank questions with the convenience and facility of machine-assisted scoring, class statistics and item analysis. It is essentially a machine-scored "fill-in-the-blank" test. In technical terms, the MDT method is all of the following: multi-digit, clued free-response, discrete answer, long-list answer bank, machine-scored testing with improved computer assisted feedback.

The MDT method entails the preparation of long alphabetical lists of possible student responses. Although 999 discrete responses can be accommodated with three-digit codes, shorter lists are fully compatible (and easier for initial list preparation). The lists may be organized into appropriate categories or printed as one continuous list. For example, in a U.S. History course, the specific categories of numerically coded answers could include: People; Organizations/Groups/Institutions; Dates/Periods; Documents; Places/Events; and Terms/Concepts. Students read a test question, think of an answer, find the response on the appropriate alphabetized list and enter the three-digit code

Figure 1-5a MDT Multi-Digit Answer Sheet (F3 with SA Questions)



MDT

MULTI-DIGIT™ ANSWER SHEET FOR

LARGE-LIST, MULTIPLE-CHOICE AND
SHORT ANSWER SA™ QUESTIONS

F3

Format 3 20:3D + 40:SC + 6:SA

Copyright© 1983, 1985 MDT Corporation

1	785
2	189
3	660
4	507
5	021
6	013
7	108
8	413
9	149
10	369
11	308
12	
13	
14	

IMPORTANT DIRECTIONS FOR MARKING ANSWERS

- Use black lead pencil only (No.2).
- Do NOT use ink or ballpoint pens.
- Make heavy black marks that fill the circle completely.
- Erase cleanly any answers you wish to change.
- Make no stray marks on either side of this answer sheet.
- Note that questions 1 through 20 involve 3-digit codes and that questions 21 through 60 are traditional multiple-choice codes with a single digit for one choice from five alternatives.
- It is optional to write your numerical answers within the three boxes above the columns of circles, BUT
- The answer that is scored is from the three circles that you blacken, one in each column.
- Unless stated differently by the examination supervisor, zeros and blanks are read the same by the computer program. Therefore, any blank column is a zero digit.
- Be sure to complete your name and social security number on the reverse side of this answer sheet.
- Write your responses to the Short Answer (SA) questions, SA101 through SA106, in the spaces provided as indicated in your examination instructions. Use extra blank pages if your instructor permits, but do NOT write anywhere else on this answer sheet. Stray marks can invalidate your entire testscore

EXAMPLE

386

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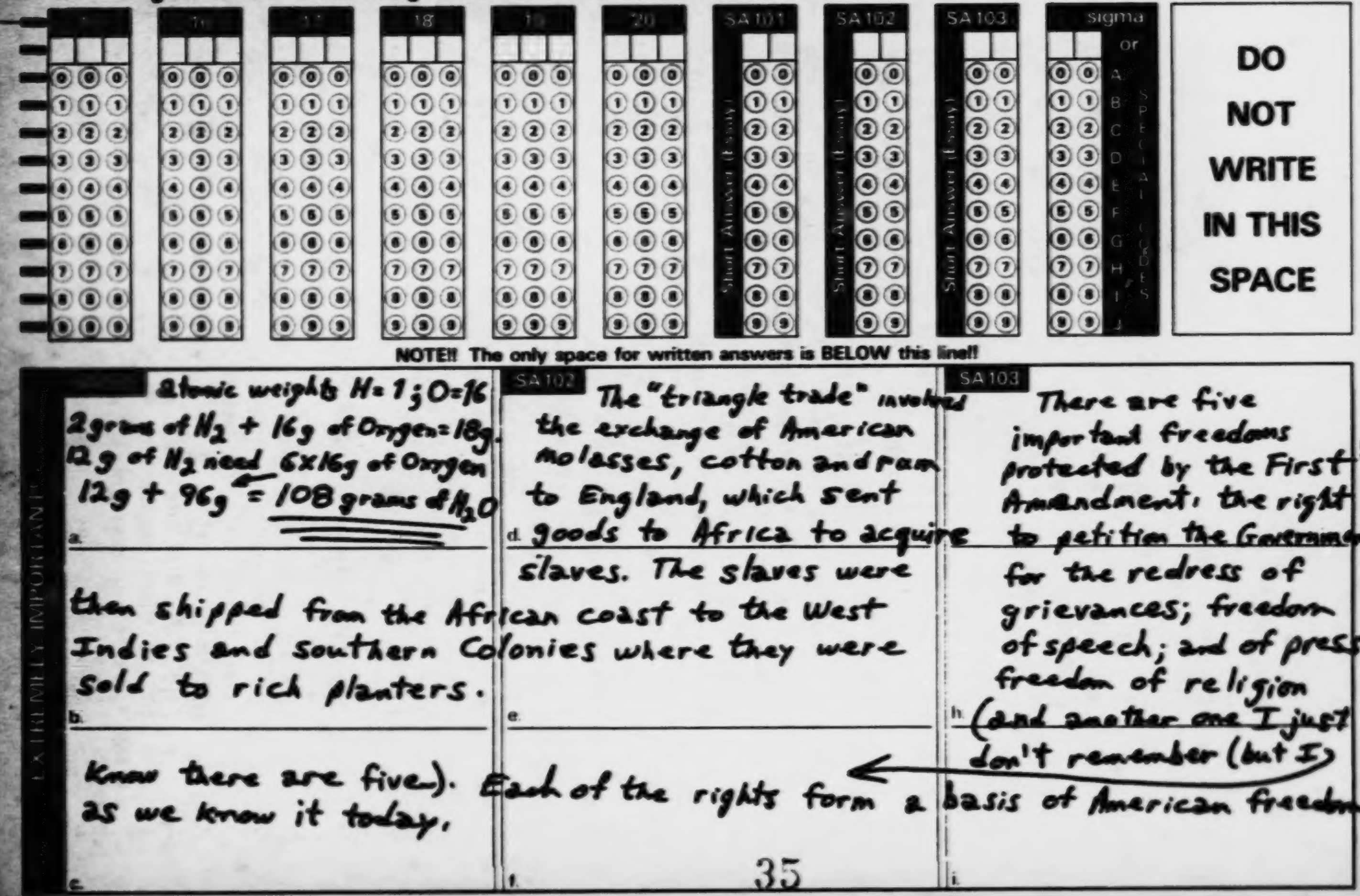
Figure 1-5b Multi-Digit Answer Sheet (continued)


16
17
18
19
20
SA 101
SA 102
SA 103
sigma
or
A B C D E F G H I J
SPECIAL CODES
Short Answer (Essay)
0 1 2 3 4 5 6 7 8 9
EXTREMELY IMPORTANT
a.
b.
c.
d.
e.
f.
h.
i.

DO NOT WRITE IN THIS SPACE

NOTE!! The only space for written answers is BELOW this line!!

Atomic weights H = 1; O = 16
2 grams of H_2 + 16g of Oxygen = 18g.
12g of H_2 need 6x16g of Oxygen
12g + 96g = 108 grams of H_2O

SA 102

The "triangle trade" involved the exchange of American molasses, cotton and rum to England, which sent goods to Africa to acquire slaves. The slaves were then shipped from the African coast to the West Indies and southern Colonies where they were sold to rich planters.

SA 103

There are five important freedoms protected by the First Amendment: the right to petition the Government for the redress of grievances; freedom of speech; and of press; freedom of religion (and another one I just don't remember (but I know there are five). Each of the rights form a basis of American freedom as we know it today.

on the specially-formatted MDT machine scannable answer card or sheet or special page for manual grading.

The phrasing of questions is similar to fill-in-the-blank tests or the stems of multiple choice questions. Hundreds of questions can be made for a single long-list answer bank, making question generating faster since there is no need to specify incorrect foils. MDT multi-digit tests can be graded manually or by card or sheet scanners either with a mainframe or microcomputer.

In Chapters Four and Five there are complete descriptions of the main components: the computer, optical mark scanners, software, answer forms and long lists. These components are integrated into a system of testing which is both challenging and complete. It is compatible with all existing machine-scored testing methods.

The MDT testing innovation was developed in 1982-83 by Paul S. Anderson to meet his own needs as a professor of Geography at Illinois State University. Since that time, Anderson has improved the multi-digit testing for his own classes, and has conducted pilot research on the educational implications of the MDT techniques. His academic papers and publications (see Bibliography) are integrated into this book along with relevant research by others. Future research topics are suggested in appropriate sections. One of the key hypotheses behind MDT testing is that appreciable gains in cognitive achievement and retention should be made by students preparing for an MDT answer bank test in comparison with others studying for traditional multiple choice five-foil tests.

Although only in use since 1983, the MDT system has developed beyond a simple testing method to thwart the good guesser. Several other features have been developed:

1. Improved feedback for students and teachers;
2. Instant scoring for in-class positive reinforcement of learning;
3. Basic hardware modifications to lower financial costs;
4. Unique short answer (SA) capabilities to facilitate the inclusion of essays or written answers such as equations and calculations.
5. A microcomputer grade book loaded directly from the scanner files.

Each of these innovations plays a supporting role in saving time when test-making, grading and record-keeping.

Teachers can use this time for tasks machines cannot perform.

The capabilities of electronic devices such as computers and optical mark readers (OMRs) have been expanding exponentially, but their applications in testing have barely changed in several decades. It will be many years before tests for large classes will be taken with every student at a computer terminal--and even then part of the tests might have an MDT multi-digit format. Furthermore, tests for small classes may remain handwritten or only partially computer-scored for decades to come. A better, more challenging usage of existing electronic devices has been needed, but with the answers marked on paper for mass grading. In this light, the MULTI-DIGIT test procedure appears to be the first truly significant innovation in computer-scored measurement in several decades. It can be used in every discipline and at almost every level of education, especially in high school and post-secondary situations.

1.4 Conclusion

The MDT multi-digit test method is not a panacea for the problems of education in America, but it is a step toward increased academic excellence. It is the tip of an iceberg of new computer-assisted testing. It has potential for rapid, cost-effective improvement of education by combining new ideas with the machines already purchased for use with the ubiquitous single-digit "choose-it-out-of-five" testing. Already the long-list method has been disseminated to a variety of colleges to evaluate its educational capabilities. As a larger pool of experience, lists, answer forms, software and support items become available, the MULTI-DIGIT test will become a widely accepted additional measurement tool that literally thousands of teachers use in innumerable ways with millions of students.

MULTI-DIGIT Testing combines computer technology
and educational innovations to strengthen
academic excellence in America.

Chapter Two

Origins of the MDT Method (1982-1983)

The MULTI-DIGIT long-list testing method is unique and the result of continual development since 1982. Prior work by others with related testing formats (discussed in Chapter Eight) never achieved computer scoring of coded multiple digit answers. Those other formats were unknown to Professor Anderson when he originated and operationalized the multi-digit testing method for use with his classes. Since the initial development period was only an attempt to meet his personal classroom needs, this chapter is narrated in the first person.

2.1 Background For Innovation

It is perhaps appropriate that this system was devised by an individual with my background. As an American born just before the Baby Boom, I went through high school and college when the multiple choice method of testing was gaining major acceptance for educational testing. I remember well punching pin holes in the desired spots and using special high-reflectance marking pencils (used prior to the now all-powerful "No. 2" pencils). Having grown up with full exposure to those testing methods, I was reasonably comfortable with objective educational testing. My Army training also involved extensive use of the multiple choice method. In graduate courses, I did not have much exposure to such testing except in taking entrance examinations.

For fourteen of the eighteen years following my undergraduate degree, I lived overseas. Six of those years (1972-77) were in Australia where I completed my doctorate. I never had any machine-scored testing during those studies. Simultaneously, I also began my university employment, first as a graduate assistant and later as a full-time lecturer. In Australia the use of multiple choice or machine-scored testing was not considered an acceptable alternative. Like

British education, the Australian system requires written answers to essay or short answer questions.

I also lived in Latin America for seven years, including four and a half (1978-82) as an assistant professor at the University of Brasilia. Five-choice tests were used for university admissions purposes in Brazil, but the machines and answer sheets were not available for use in course work testing. Furthermore, it was not really necessary because of relatively small class sizes and a normal teaching load of two courses per semester.

In mid-1982 I returned to the United States to become an Assistant Professor of Geography at Illinois State University (ISU). During the first semester, I had relatively small classes and did not use any machine scoring. But at that time I was informed that in the spring semester I would be teaching a class of eighty-eight students studying World Regional Geography. The typical teaching load at ISU is four courses per semester, and it was clear I would have to change my essay and short answer testing methods to utilize the available computer-scored testing techniques. After all, I said to myself, I am now in America, "Land of the free and home of the multiple choice."

Part of the World Geography course content (and I emphasize it is only one part) is learning appropriate place names for countries, cities, rivers, mountains, etc. Americans are notorious worldwide for their geographic ignorance; they should have learned the basic facts in earlier grades. I knew some of my students would not be able to name or to find on a map some of even the most basic geographic information, such as "name the capital city of France" or "identify Brazil on a world map." These questions could be appropriately asked as an open-ended or fill-in-the-blank question, but they would be ludicrously easy when offered in a choose-it-out-of-five multiple choice mode. Quite honestly, I could not think of four reasonably plausible alternatives to use with the name of Paris as the five choices from which the students would select the name of the capital of France.

The obvious answer to this educational dilemma was that there should not be merely five choices, but a very large list of choices. In fact, the list should be almost as big as the gazetteer which names the places in an atlas. I could give each one of those names a distinctive code number, I thought, and then the computer could do the scoring.

2.2 An Operational Prototype

Being a geographer with a strong physical science background and an infatuation with the power and versatility of computers, I knew that available technology could perform almost any task once the problem was systematically described. During the fall semester of 1982, the system began to come together as I studied the intricacies of optical mark readers, commonly known as OMRs or scanners. The hardware is far advanced over the applications. I realized that almost any configuration on a scannable sheet could be used as the input arrangement. The particular machine and system available at ISU fortunately had capabilities of "darkest mark discrimination," an important feature lacking in the less expensive (under $2500) scanners. (The various hardware options are discussed in Chapter Four.) Therefore, I was free from hardware limitations for scanning and computing. Apart from the machinery (the scanner) and the actual writing of the test questions, the three essential and missing elements of my new testing method were the answer sheet, the computer program and the long list.

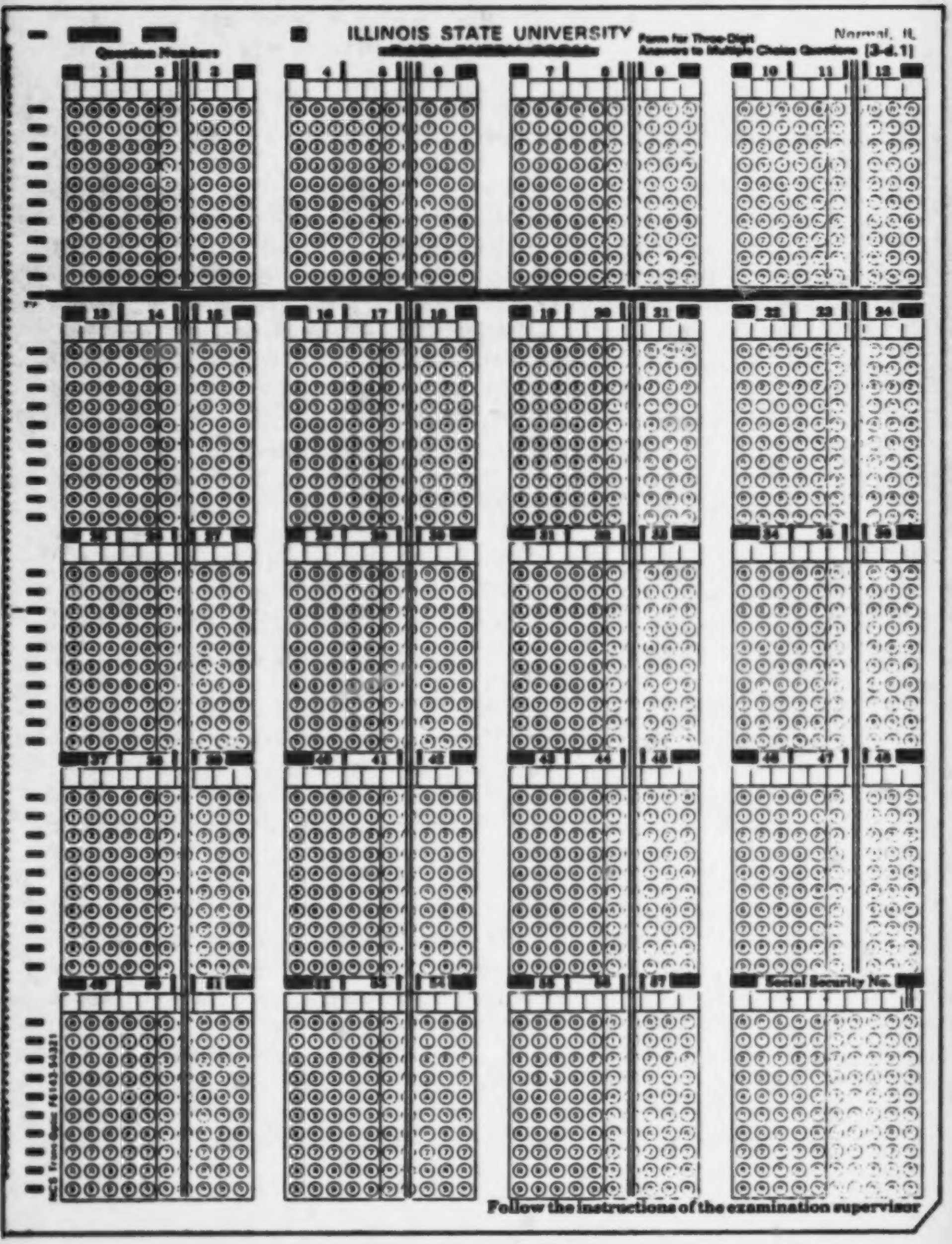
I discussed with computer programmers at ISU the prospects of having a software program to score three-digit answers. They assured me the program could be written and could, in its prototype form, utilize standard statistical analysis package. Computer programming funds were obtained through the Department of Geography-Geology at ISU for the initial prototype program to be written for use in my classes. Additional seed funds were obtained from the ISU Instructional Development Program for programming and printing. [Little did I know that eventually tens of thousands of dollars, excluding my own hours of work, would be needed during the next four years of refinement and further development.]

The answer sheet presented a more difficult problem. My training in Cartography and Remote Sensing made me familiar with (1) the printing processes involved with making answer sheets, and (2) the spectral reflectance of electromagnetic energy, the physical foundation for optical mark readers. With any optical mark reader (OMR), specific cells or grids on the answer form are subject to the sensing of pencil marks. All of the cells are sensed each time, whether there is a mark or not. A software program in the scanner or computer actually "resolves" the sheet into specific groups of cells for each question. Therefore, my grid for student responses could be placed anywhere on the scannable page, but any printing on the page would either have to be in nonphotosensitive ink (a relatively costly and precise printing job) or it had to fall into the "between-cell" spaces where the machine would not detect ink or pencil marks. My solution was to modify a data entry sheet which had twenty blocks for ten-digit numbers primarily used for the entry of numerical values from surveys or research. As shown in Figure 2-1, a black overprint format was designed to subdivide each ten-spaced answer area (in blue ink) into three groupings with three-column widths for each of the test questions. The printing service at ISU completed the final drafting and printing of the overprint.

The third element was the list or "answer bank". For the initial test I did not attempt to make a long list of geographical concepts. The only items desired were the geographical features of the world. An appropriate listing was found in a gazetteer of a small atlas. With the help of a graduate assistant, the items on the list were subdivided into the major categories of Political Units, Water Features, Terrain Features and Cities. There were far too many items for the intended list of nine hundred ninety-nine options, so we had to eliminate the least desirable ones. At that time there was no specialized MDT List Maker program and the Department of Geography-Geology did not have a word processor. Therefore, we had to cut and glue over 900 terms onto two sheets of paper and then number each term by hand. It was like putting together a jigsaw puzzle! (Sections of one of those pages are attached as Figure 2-2.) The patience and time availability of the graduate assistant were soon exhausted, and the task fell entirely on me. By this time the spring semester had already begun and the students had been told they would be having the multi-digit long list type of test. However, with only one week before the first test date, the computer program, the answer sheet and long lists were not finished.

I remember all too clearly a full week of working until two or three in the morning to finalize the crucial components. The answer sheets came back from the printer two days before the first test. The long list answer bank was finalized and sent for multiple photocopies on the morning of the test. I also prepared the examination and the numbered outline maps. The students took the first

Figure 2-1 First Multi-Digit Computer Scored Answer Sheet (Reduced; Black overprint on blue response circles)


ILLINOIS STATE UNIVERSITY
Form for Three-Digit Answers to Multiple Choice Questions
Normal, IL
[3-d.1]
Question Numbers
Social Security No.
Follow the instructions of the examination supervisor

multi-digit test at the appointed hour. The computer program for scoring was ready several days later. I handed back the students' scores two class periods after they had taken the test. Quite frankly, I gave a great sigh of relief! I also knew the multi-digit test could now be used repeatedly with great ease.

2.3 The First Multi-Digit Test

The crucial question is not whether the system functions physically, but whether it functions pedagogically. The class of World Geography students had been informed from the very first day of class that a distinctive testing method would be used, and that it would be a machine-scored approximation of a fill-in-the-blank test for the place name component of the course. Nothing was available to show the students; there were no answer sheets, no long lists and no samples of computer printout.

The testing conditions were less than ideal. The classroom was jam packed, and each student only had a single chair with the armrest style of writing space. With the help of an assistant, the pieces of paper were distributed. It then took a full fifteen minutes to familiarize the students with the functional aspects of the long lists and answer sheet, a task which can now be easily accomplished at the beginning of the semester (see Chapter Seven). Fortunately, the class session was seventy-five minutes long; the vast majority of the students were able to complete the test within the allotted time. Those students needing more time were accommodated in the few minutes after the normal class period. Finally two students were taken to my office to finish the test at a more leisurely pace. From the beginning, these tests were not intended to be a "race against the clock."

Having no previous experience as to how this method would function, I conducted a simple exit survey as the students were leaving the room. In the corridor, I asked for their opinions. Some students bluntly said they disliked it, but acknowledged that it was the instructor's prerogative to determine the testing method. These same students when asked if they would prefer the long-list method to a fill-in-the-blank test, were in almost unanimous agreement. They preferred the one in which there was a list (although large) from which they could make choices.

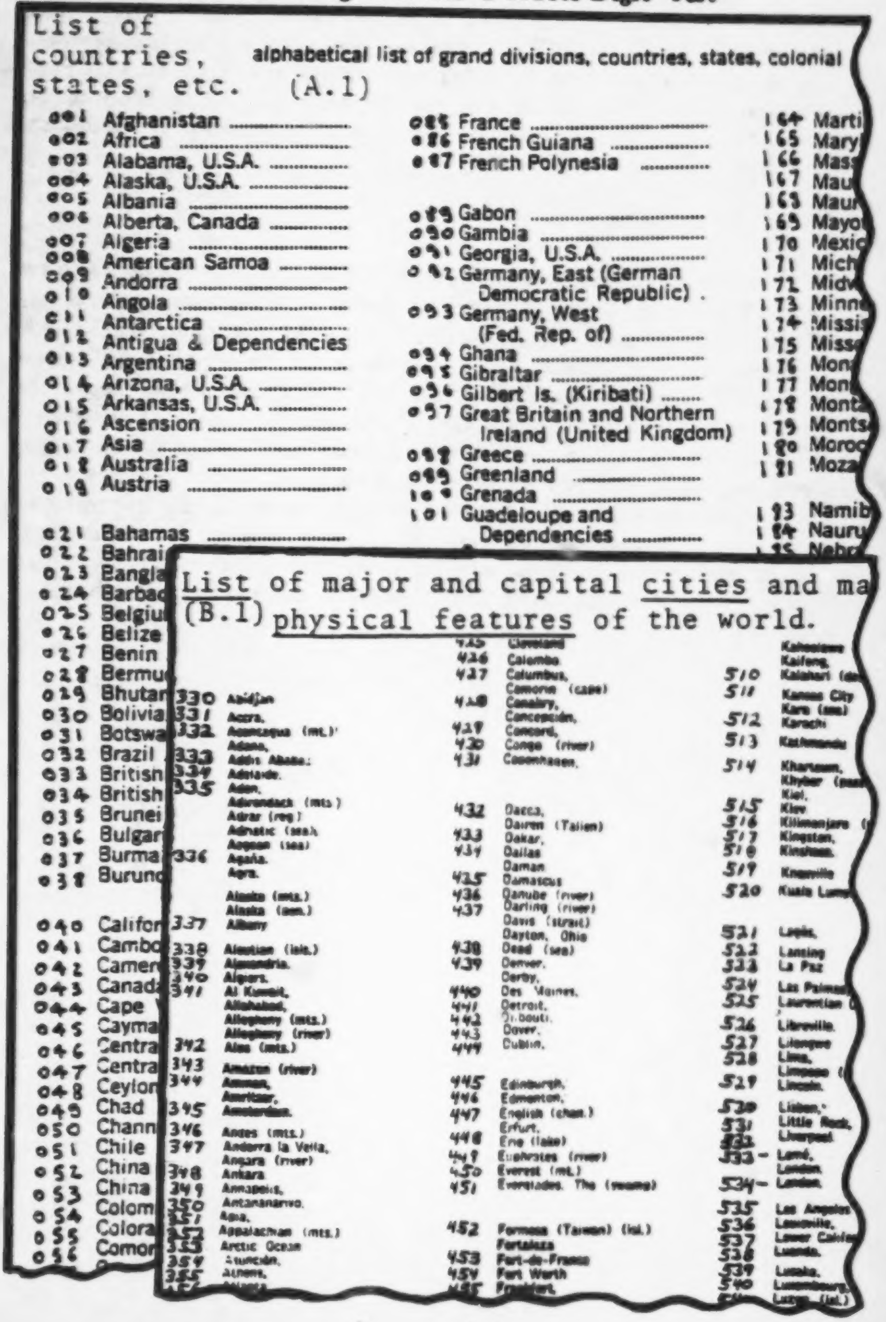


Figure 2-2 First Long List for a Multi-Digit Test

List of countries, states, etc. (A.1)

alphabetical list of grand divisions, countries, states, colonial

001 Afghanistan
002 Africa
003 Alabama, U.S.A.
004 Alaska, U.S.A.
005 Albania
006 Alberta, Canada
007 Algeria
008 American Samoa
009 Andorra
010 Angola
011 Antarctica
012 Antigua & Dependencies
013 Argentina
014 Arizona, U.S.A.
015 Arkansas, U.S.A.
016 Ascension
017 Asia
018 Australia
019 Austria

021 Bahamas
022 Bahrai
023 Bangla
024 Barbad
025 Belgiu
026 Belize
027 Benin
028 Bermu
029 Bhutan
030 Bolivia
031 Botswa
032 Brazil
033 Britisn
034 British
035 Brunei
036 Bulgar
037 Burma
038 Burund

040 Califor
041 Cambo
042 Camer
043 Canada
044 Cape
045 Cayma
046 Centra
047 Centra
048 Ceylon
049 Chad
050 Chann
051 Chile
052 China
053 China
054 Colom
055 Colora
056 Comor

085 France
086 French Guiana
087 French Polynesia

089 Gabon
090 Gambia
091 Georgia, U.S.A.
092 Germany, East (German Democratic Republic) .
093 Germany, West (Fed. Rep. of)
094 Ghana
095 Gibraltar
096 Gilbert Is. (Kiribati)
097 Great Britain and Northern Ireland (United Kingdom)
098 Greece
099 Greenland
100 Grenada
101 Guadeloupe and Dependencies

164 Marti
165 Mary
166 Mass
167 Mau
168 Maur
169 Mayo
170 Mexic
171 Mich
172 Midv
173 Minn
174 Missis
175 Miss
176 Mon
177 Mon
178 Monta
179 Monts
180 Moroc
181 Moza

193 Namib
194 Nauru
195 Nebr

List of major and capital cities and ma
(B.1) physical features of the world.

330 Abidjan
331 Accra,
332 Aconcagua (mt.)
Adana,
333 Addis Ababa,
334 Adelaide.
335 Aden,
Adirondack (mts.)
Adrar (reg.)
Adriatic (sea)
Aegean (sea)
336 Agaña.
Agra.
Alaska (mts.)
Alaska (pen.)
337 Albany
338 Aleutian (isls.)
339 Alexandria.
340 Algiers.
341 Al Kuwait,
Allahabad,
Allegheny (mts.)
Allegheny (river)
342 Alps (mts.)
343 Amazon (river)
344 Amman,
Amritsar,
345 Amsterdam.
346 Andes (mts.)
347 Andorra la Vella,
Angara (river)
348 Ankara
349 Annapolis,
350 Antananarivo,
351 Apia,
352 Appalachian (mts.)
353 Arctic Ocean
354 Asunción,
355 Athens,

425 Cleveland
426 Colombo
427 Columbus,
Comorin (cape)
428 Conakry,
Concepción,
429 Concord,
430 Congo (river)
431 Copenhagen,
432 Dacca,
Dairen (Talien)
433 Dakar,
434 Dallas
Daman
435 Damascus
436 Danube (river)
437 Darling (river)
Davis (strait)
Dayton, Ohio
438 Dead (sea)
439 Denver,
Derby,
440 Des Moines,
441 Detroit,
442 Djibouti,
443 Dover,
444 Dublin,
445 Edinburgh,
446 Edmonton,
447 English (chan.)
Erfurt,
448 Erie (lake)
449 Euphrates (river)
450 Everest (mt.)
451 Everglades, The (swamp)
452 Formosa (Taiwan) (isl.)
Fortaleza
453 Fort-de-France
454 Fort Worth
455 Frankfort,

Kahoolawe (
Kaifeng,
510 Kalahari (de
511 Kansas City
Kara (sea)
512 Karachi
513 Kathmandu
514 Khartoum,
Khyber (pa
Kiel,
515 Kiev
516 Kilimanjaro (
517 Kingston,
518 Kinshasa,
519 Knoxville
520 Kuala Lum
521 Lagos,
522 Lansing
523 La Paz
524 Las Palmas
525 Laurentian (
526 Libreville,
527 Lilongwe
528 Lima,
Limpopo (
529 Lincoln,
530 Lisbon,
531 Little Rock,
532 Liverpool
533 – Lomé,
London,
534 – London
535 Los Angeles
536 Louisville,
537 Lower Califo
538 Luanda,
539 Lusaka,
540 Luxembourg,
Luzon (isl.)

Approximately an equal number of students found no objections to the test, and I also began to hear the comments such as: "You really have to know the answers with this type of test." Perhaps the most significant fact was no students went to the department chairperson or to the college dean to file complaints against me and my method of testing.

2.4 Conclusion

During those weeks before the debut of what is now the MDT multi-digit testing method, I did not realize the full impact and potential for multi-digit answer bank testing in education. The awareness of its potential grew when Professor Rayfield told me the conversation found in the first introduction in Chapter One. I knew the method had a desirable impact on the students when used with appropriate subject matter. Numerous improvements were made to the system, many of them in response to suggestions by the initial group of students. I continued to experiment with additional options and enhancements during the four years between its debut and the first edition of this book.

Chapter Three

Pioneer Experiences (1983-1986)

3.1 The Pioneer Users

The history of the development of MDT multi-digit testing would not be complete without mentioning the pioneers who participated in the early use of this innovation. The nucleus has been small and the number of disciplines few, but the trends are very clear and strong.

In the second semester of development (Fall 1983), the multi-digit test method was used not only by Paul Anderson but also by Deborah Gentry in Home Economics and by Charles Stokes in Music. Both of these individuals slightly modified their existing hand-scored fill-in-the-blank style tests to use the MDT capabilities. Their class sizes were relatively small, but their efforts demonstrated the MDT method could be utilized by someone other than its initial developer.

> "The MDT method has been a boon for me. It worked well and I will continue to recommend it." - Charles F. Stokes, Jr.

> "My former style of (fill-in-the-blank) testing converted easily into the MDT multi-digit format. It is a very natural way to ask questions." - Deborah Gentry.

The acceptance by Gentry and Stokes matched with the continuing work by Anderson. These earliest experiences lead to further project development and the writing of the first conference paper (Anderson, 1983, published in 1984a). These experiences clarified the utility of multi-digit testing for wide usage in education. Development work beyond the first prototypes was definitely justified.

In the spring semester of 1984, the first specially designed MDT answer sheet was printed (Figure 1-2). (With only minor appearance changes, that answer sheet is widely used and referred to by the code number F1.) Its availability almost totally eliminated the most frequent student criticism that the initial prototype answer sheet was very difficult to read and mark carefully (Figure 2-1). The number of student encoding errors, which have been carefully monitored in the development years, was greatly diminished.

During the spring 1984 semester, an exploratory research effort was conducted by four Geography faculty members at ISU: Paul S. Anderson, Miriam H. Hill, Shamim Naim and William Walters, Jr. Their combined classes provided a sample population of nearly two hundred students. The results of the research have been published (Anderson et al, 1985) and are reprinted in Chapter Eight of this book. In addition, David Paul Davenport in the Department of Geography-Geology used the MDT method in his Earth Science classes.

> "This [MDT] method is great for courses that introduce scientific terminology. The recognition and 'process of elimination' factors are gone. It really identifies the unprepared students." - David Paul Davenport

During the summer of 1984, the first version of the MDT List Maker program was written. This program (described in Chapter Five) greatly facilitates the making of lists. List making had been the major stumbling block to the adoption of the MDT method by other instructors.

The research emphasis continued during the fall 1984 semester when Eileen Kanzler started using the MDT technique in her American History classes at University High School, a laboratory school at Illinois State University. Kanzler was the first person to utilize the MDT method in secondary education, and consistently her results have been favorable.

> "The MDT method is a most satisfactory substitute for the multiple choice and fill-in-the-blank test in the area of testing for recall of factual detail . . It is an important tool to establish a pool of basal information. In the past (teachers) have presumed a lot of basal

> knowledge that in fact has not been learned." - Eileen M. Kanzler

Anderson and Kanzler conducted research which resulted in two joint conference presentations (1985a and 1985b). The university laboratory schools at ISU funded a research assistant to help operationalize the MDT techniques. During the spring semester of 1985, over three hundred students at Illinois State University were given tests in their various classes using multi-digit methods.

In June 1985 Douglas Hartley of the ISU Art Department tested the method with one of his classes of fifty summer school students; he subsequently used it in the fall semester with classes totaling two hundred fifty students. Professor Hartley has experimented with the predistribution of his printed long list for his Art Appreciation students. They may use the list for study purposes or when attending lectures. It helps them become more familiar with the terminology and better prepared for their examinations.

> "The results (of a class survey) were overwhelming. Fifty-two out of sixty (87%) students recommended that I continue this MDT testing method for further courses." - Wm. Douglas Hartley

In the fall of 1985 Diane Alexander of the Department of Criminal Justice Sciences utilized the MDT method with her class of over three hundred fifty students. Her experiences were quite favorable, and in the spring 1986 semester, the entire enrollment of one thousand two hundred students in the Introduction to Criminal Justice Sciences course she coordinates were given tests with the MDT products. Her efforts have brought the multi-digit method to the largest class sizes thus far.

> "The MDT method eliminates guessing. Due to this drastic difference, students quickly learned they could not 'pull an all nighter' and pass the MDT test. The students knew what was expected of them and they had to study harder or modify their current study habits. The MDT style provides credit for student studies. An appreciation for this new testing format was expressed by students at the end of

> the semester. It presented them with a greater challenge, the questions were more interesting and fun and they knew what was expected of them . . . The benefits of using the MDT method are more than just the recall of memorization of terms and other factual recall. (Students) develop a working vocabulary . . . and apply facts and concepts because students incorporated them in their conversation." - Diane Alexander

Another user of the MDT method for multiple courses in the Department of Criminal Justice Science is Peggy Fortune.

> "In using the MDT method I can put a test together in half the amount of time. I just ask the question. There's no need to come up with four distractors for each question. With analysis questions, the students have to understand, think and then draw logical conclusions without gigantic hints." - Peggy Fortune

During each of the spring and fall semesters of 1986, approximately two thousand five hundred students (about three percent) of all course enrollments at Illinois State University had MDT style examinations. The departments using the method include Military Science (ROTC) and Mathematics.

> "Large organizations like the Armed Forces or corporate giants invest heavily in training to insure uniformity and quality control in world wide operations. The MDT techniques are highly appropriate for training programs. Easily generated fill-in-the-blank style questions, with automated scoring and computer-assisted analyses will help us train better and measure how much the students actually know. - Larry Wexler, Cpt.

> "With the MDT method I can have machine-scored exams but my students still have to make the computations and enter their own answers on the form. They no longer have the comfort zone of five choices. Now an important challenge is for the instructor to design questions which

subdivide the tasks of computations and processes into discretely identifiable segments which can be tested as the student proceeds to answer each main question. The MDT technique has considerable promise in testing mathematic concepts. I like it." - Michael Kasper

3.2 Student Attitudes About The MDT Method

Student evaluations and comments about the MDT method for seven semesters in the World Geography course have been consistent. As expected, student reactions are mixed. Unfamiliarity with the method, an additional sheet of paper on the desk and the increased question difficulty (in contrast to five-choice questions on the same subject matter) lead about half of the students to consider the MDT method to be less desirable than the traditional multiple-choice method. However, those students readily prefer the MDT answer bank method when given the choice between it and full free-response questions (fill-in-the-blank).

The other half of the students consider the MDT method to be equal to or preferred over the multiple-choice style. The following is a sample of their comments:

> ". . . studied a great deal more . . . shows that the individual knows the material or not, he can't guess . . ." S.B.
>
> ". . . really have to know the information . . ." S.N.
>
> "First time taking an Exam like this!!! I like (it)." G.T.
>
> "I liked the MDT test system." T.H.
>
> ". . . great idea!" L.A.
>
> ". . . liked the idea . . . more effective in determining if the students really know the information . . . you either know it or you don't." R.B.

"I think the MDT test method is very effective in that it contains the best aspects of both the multiple choice test and the fill-in-the-blank test method. It negates the problem of lucky guessing common to multiple choice tests but at the same time allows recall of answers "on the tip of your tongue" by being able to see the name on a list. It also doesn't bring with it the problem of learning how to spell strange names correctly, a problem common to fill-in-the-blank tests." P.D.

". . . good test method . . ." K.B.

"I like the MDT method. I feel it provides a much more accurate score when an evaluation of a student's knowledge is being attempted . . . If I know I would be faced with a MDT test . . . the motivation to study would be greatly enhanced. MDT tests will raise retention and lower unearned grades." R.E.

3.3 Commercial Availability And Dissemination Beyond ISU

Press coverage, specifically an article from the Associated Press in late May 1985 (Figure 3-1), attracted substantial nationwide attention. Individuals from Seattle to Philadelphia subsequently wrote or called for further information. From those inquiries, five institutions were selected to be the recipients of grants of the MDT materials. The grants were initiated with the assistance of the Department of Geography-Geology at ISU, a seed money dissemination grant from Colonial Ice Cream Inc. of St. Charles, Illinois, and the MDT Corporation. The five selected institutions were University of Washington (Seattle), Oklahoma State University (Stillwater), University of Illinois (Champaign-Urbana), Aurora University (Aurora, Illinois) and Jefferson Medical College (Philadelphia). The grant program provided computer software, a modest supply of answer sheets and consulting assistance to make the MDT system available at those institutions. During 1985-86, these schools began to establish capabilities for operation on each campus. Lost mail, computer incompatibilities, difficulties with early versions of software, and general unfamiliarity with multi-digit testing slowed the progress. However, much has been learned and incorporated into the programs and into this book.

In the late spring and summer of 1985, the MDT project entered into a stage of commercial product development. The Multi-Digit Technologies Corporation was formed to handle the business aspects of the MDT project. Substantial state funding from the Technology Commercialization Center (TCC), directed by Illinois State University, greatly accelerated the refinement of the prototypes into commercial products. The Multi-Digit Technologies (MDT) Corporation has firmly established a unique line of MDT products and methods based on what one professor started only three years earlier as a way to improve his own classes. With the addition of several recently developed support features like instant scoring, SA questions and a microcomputer grade book, the MDT method is now commercially available to educational institutions and individual instructors.

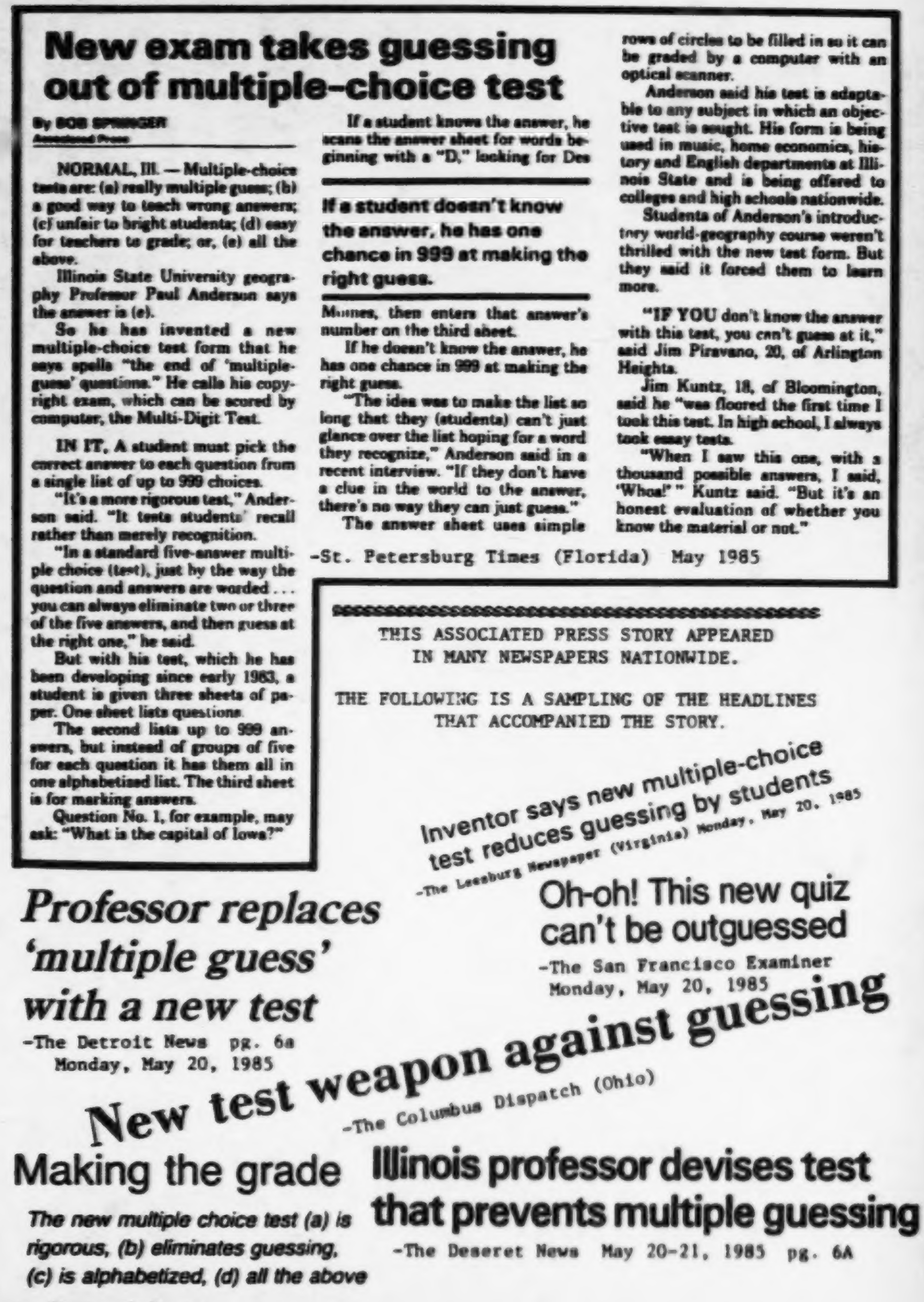
Further product development will continue even as greater emphasis is given to dissemination. The major hurdles of conceptualization, prototype operationalization, preliminary research and commercial product development have resulted in a very favorable position for the major launching of the MDT Educational System. Agreements with various manufacturers of optical scanners have also paved the way to make the MDT capabilities available at prices competitive with other optically scored testing. As more individuals and institutions join the ranks of the MDT users, further and independent research will be conducted to document the attributes of this distinctive testing method. In the near future there will be hundreds of users and then thousands; eventually the MDT innovation will become a standard option available to all professors to use as appropriate in their classes.

The MDT story is continuing. Every month brings new developments. A periodical, the MDT Bulletin, is being established to inform educators about additions in software, hardware, answer banks, research and user comments.

3.4 Dissemination And Growth

It is only natural that people intimately involved in the evolution of an innovation feel it will have far-reaching implications. However, inertia and conservative attitudes prevalent in education will make the dissemination of any

Figure 3-1 First Associated Press Coverage About MDT Methods (May 1985)



New exam takes guessing out of multiple-choice test

By BOB SPRINGER
Associated Press

NORMAL, Ill. — Multiple-choice tests are: (a) really multiple guess; (b) a good way to teach wrong answers; (c) unfair to bright students; (d) easy for teachers to grade; or, (e) all the above.

Illinois State University geography Professor Paul Anderson says the answer is (e).

So he has invented a new multiple-choice test form that he says spells "the end of 'multiple-guess' questions." He calls his copyright exam, which can be scored by computer, the Multi-Digit Test.

IN IT, A student must pick the correct answer to each question from a single list of up to 999 choices.

"It's a more rigorous test," Anderson said. "It tests students' recall rather than merely recognition.

"In a standard five-answer multiple choice (test), just by the way the question and answers are worded . . . you can always eliminate two or three of the five answers, and then guess at the right one," he said.

But with his test, which he has been developing since early 1983, a student is given three sheets of paper. One sheet lists questions.

The second lists up to 999 answers, but instead of groups of five for each question it has them all in one alphabetized list. The third sheet is for marking answers.

Question No. 1, for example, may ask: "What is the capital of Iowa?"

If a student knows the answer, he scans the answer sheet for words beginning with a "D," looking for Des Moines, then enters that answer's number on the third sheet.

If a student doesn't know the answer, he has one chance in 999 at making the right guess.

If he doesn't know the answer, he has one chance in 999 at making the right guess.

"The idea was to make the list so long that they (students) can't just glance over the list hoping for a word they recognize," Anderson said in a recent interview. "If they don't have a clue in the world to the answer, there's no way they can just guess."

The answer sheet uses simple rows of circles to be filled in so it can be graded by a computer with an optical scanner.

Anderson said his test is adaptable to any subject in which an objective test is sought. His form is being used in music, home economics, history and English departments at Illinois State and is being offered to colleges and high schools nationwide.

Students of Anderson's introductory world-geography course weren't thrilled with the new test form. But they said it forced them to learn more.

"IF YOU don't know the answer with this test, you can't guess at it," said Jim Piravano, 20, of Arlington Heights.

Jim Kuntz, 18, of Bloomington, said he "was floored the first time I took this test. In high school, I always took essay tests.

"When I saw this one, with a thousand possible answers, I said, 'Whoa!'" Kuntz said. "But it's an honest evaluation of whether you know the material or not."

-St. Petersburg Times (Florida) May 1985

THIS ASSOCIATED PRESS STORY APPEARED
IN MANY NEWSPAPERS NATIONWIDE.

THE FOLLOWING IS A SAMPLING OF THE HEADLINES
THAT ACCOMPANIED THE STORY.

Inventor says new multiple-choice test reduces guessing by students

-The Leesburg Newspaper (Virginia) Monday, May 20, 1985

Professor replaces 'multiple guess' with a new test

-The Detroit News pg. 6a
Monday, May 20, 1985

Oh-oh! This new quiz can't be outguessed

-The San Francisco Examiner
Monday, May 20, 1985

New test weapon against guessing

-The Columbus Dispatch (Ohio)

Making the grade

The new multiple choice test (a) is rigorous, (b) eliminates guessing, (c) is alphabetized, (d) all the above

-Tempe, Arizona

Illinois professor devises test that prevents multiple guessing

-The Deseret News May 20-21, 1985 pg. 6A innovation much slower than originally envisioned. For example, testing with multiple choice questions, which began in the early part of the twentieth century, required many decades before the method attained a reasonably high level of acceptance and usage. Nevertheless, Paul Anderson stands by a statement he made several years ago:

"The MDT multi-digit format of educational testing has so many favorable features that it will become part of standard educational practices in the next five to ten years."

Only a very small number of the total teaching population has been aware of the existence of the MDT testing method and an even smaller group has utilized it in their classrooms. However, as of this writing in late 1986, all **instructors who have ever written an MDT style test and utilized it continue to recommend the testing method for use in appropriate places within their disciplines.** Over two dozen professors are in this category. (Only a few have stopped using it, mainly for administrative reasons.) These pioneer professors reveal a potentially powerful trend toward acceptance. The expansion of usage has been exponential, doubling each semester (quadrupling each year) for three years. The size of the educational community could sustain such growth for a decade or two. The key is to have teachers try it. Those that do soon realize the power and benefits offered.

3.5 Conclusion To Part A

The preceding three chapters have been descriptive. The MDT multi-digit testing was introduced through a true story, a sample test and a discussion of the MDT testing innovation. The evolution of the method has been related. Chapter Three recalled the early days of the pioneers who contributed to its development.

The chapters which follow in Part B provide a practical nuts and bolts description of the MDT innovation. Those chapters (four though seven) do NOT need to be read before studying the educational issues and related research in Part C. These two parts should help to answer questions such as the following: How can a teacher/professor get started with the MDT method? What instructions do students need? What research has been done? How does it relate to Bloom's hierarchy of learning? What are the financial implications for education? All of those chapters illustrate how MULTI-DIGIT long-list testing combines computer technology and educational innovations to strengthen academic excellence in America.

PART B

Operational and Administrative Issues

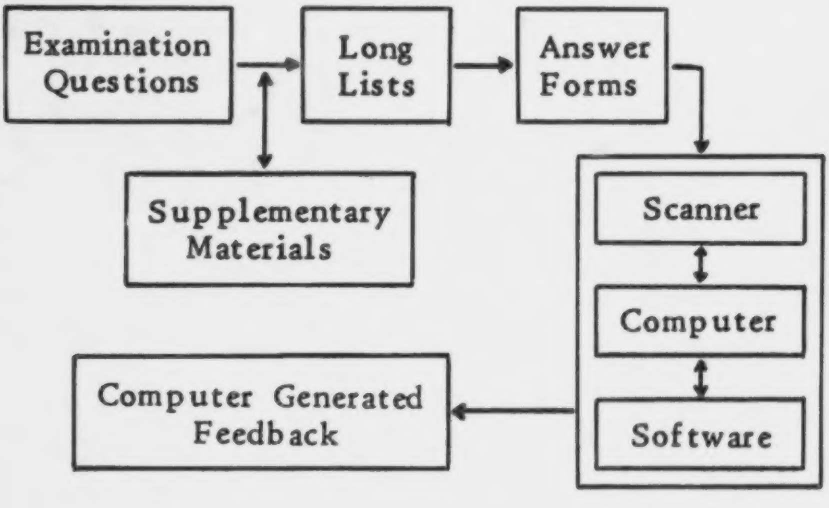
The four chapters in this Part provide a practical, nuts and bolts description of the operation of the MDT multi-digit method of testing. Each of the seven essential components of the MDT Educational System are described and discussed. They range from computer hardware down to single sheets of paper with long lists and questions. As shown in Figure 4-1, four of these components are very tangible items which constitute an operational system: computer; optical mark reader (OMR or scanner); computer programs; and answer forms. The other three items are more directly under the control of the instructor: long lists for the selection of answers; questions asked; and any supplementary materials.

Chapter Four is especially important for administrators and support staff. It discusses the hardware and software options for a functional MDT Educational System. That information may seem unnecessary for teachers where the system is already available and maintained by a support staff of computer operators and secretaries. However, enthusiasts for improved testing might like to know the options available for hardware and software. Furthermore, the microcomputer version of the MDT System can be operated by individual teachers.

Chapters Five, Six and Seven are written specifically for the instructor and focus on printed materials. In spite of all the high technology associated with hardware and software, most educational measurement depends on "paperware." The assessment components students and instructors see most (except in oral exams and those taken at individual computer terminals) are printed on paper. A broad definition of "paperware" for testing includes mimeographed question pages, answer sheets, photocopies, true photographs and even some transparencies; they are all essentially printed pages which can be handled, read and/or marked manually. While technology moves the testing frontiers ahead, the mainstay remains these "user-friendly" sheets of paper. Via paper the MDT Educational System is able to utilize technology without disrupting the established nature of testing or requiring massive funding to provide every student with a networked computer terminal. The MDT innovations will certainly keep pace with future technological shifts, but for the present, "paperware" is still the undisputed king of materials for educational measurement.

The five printed components seen by students are the answer forms, long lists, pages with the test questions, any supplementary materials and computer-generated feedback. The specifics of making and using these items are in Chapters Five through Seven which cover preliminary preparations (Chapter Five), test generation (Chapter Six) and actual classroom activity (Chapter Seven).

Figure 4-1 Diagram of Components in the MDT Educational System


Examination Questions
Long Lists
Answer Forms
Supplementary Materials
Scanner
Computer
Software
Computer Generated Feedback

Together, the hardware, software and paperware constitute a functional system appropriate for every academic discipline and nearly every educational situation. Although this book can include only a few examples, virtually all disciplines have some course content that could be appropriately evaluated utilizing the MDT testing method. With the exception of special education (handicapped) and maybe the initial years in elementary school, almost every educational situation can utilize the multi-digit testing method. The examples given in the following chapters could be modified to be more (or less) difficult in accordance with the appropriate grade levels. For the most part, the examples relate to students in high school, undergraduate or adult education.

Chapter Four

Hardware and Software Components

Once a particular system has been decided upon by a school and is operational, very few of the hardware and software differences are of importance to the individual instructor. To utilize the system, the instructor only needs to have an appropriate list, questions for a test and a pile of answer sheets. The rest of the system (computer, scanner and software programs) should already be in place.

On the other hand when selecting new equipment, there can be substantial variations in the configuration of the hardware and software components for the MDT System. Each combination has distinct advantages. In selecting the appropriate system of hardware and software the technical information below plus specific manuals available from the Multi-Digit Technologies Corporation should be utilized to their fullest extent. The decisions will become relatively easy and the MDT Educational System can be ready for use with a minimum of effort.

4.1 Computers

Computers come in many sizes, shapes and price ranges. The MDT Educational System is designed to work on almost any computer except the smallest home models. Thus, the range extends from the large mainframe computers through the minicomputers to microcomputers. The latter are particularly important as they are becoming more readily available in educational institutions and are frequently found even in the offices and classrooms of teachers.

4.1.1 Mainframe Computers: For large-scale applications, such as at universities where hundreds of thousands of machine-scored tests are given each year, the speed and cost efficiency of mainframe computers is highly desirable if the test scoring is centralized. Most universities have already made the investment in a mainframe computer and its availability should not be overlooked. In these cases, there is no need to purchase additional computing power (unless some of the unique advantages of the MDT software on microcomputers are desired).

The mainframe versions of the MDT computer programs are written in FORTRAN-77, the most commonly available and used scientific computer language. The discussion of the MDT software for mainframe computers is in Section 4.3.1.1 of this chapter.

4.1.2 Minicomputers: To the extent a minicomputer can also operate FORTRAN or BASIC programs as prepared for the mainframe or microcomputers, MDT capabilities are available on minicomputers of almost any type. Otherwise, availability will depend on user demand and available funds for software modifications.

4.1.3 Microcomputers: To operate on microcomputers, the MDT system requires at least (1) an acceptable disk operating system (DOS); (2) 256K of RAM memory; (3) one disk drive; (4) a printer and printer port; and (5) an RS-232C serial port to which the OMR scanner can be connected. (Note: The continual development of MDT software for use on a variety of machines will result in frequent changes to the following list. This listing is intended to be accurate as of late August, 1986. However, any questions concerning availability for these and any other microcomputers should be directed to the MDT Corporation which can provide more current information.)

4.1.3.1 IBM-PC and compatibles: The MDT microcomputer programs were initially written to operate with MS-DOS on the IBM-PC compatible microcomputers. Those machines include: 1) IBM-PC, XT, AT; 2) COMPAQ (all models); 3) TANDY 1000, 2000; and 4) some models of Zenith, Columbia, Toshiba and other microcomputer manufacturers.

4.1.3.2 Apple computers: The computers from Apple have a variety of disk operating systems and other configurations. The most common, the Apple IIe is widely used in education, but is basically inadequate for the large MDT programs. The new (1986) Apple II GS has sufficient computing capabilities and speed for the MDT software requirements. The MDT system should be available on it in 1987. Availability on the Macintosh will depend upon an indication of demand.

4.1.3.3 Other microcomputers: The MDT computer software may also become available on the many other machines which operate with CP/M and TRS-80 disk operating systems. However, numerous questions concerning hardware adequacy and the interfacing of the various optical mark readers (scanners) for the input of data into the microcomputer will have to be resolved.

4.2 Optical Mark Readers (OMRs = Scanners)

Of the various optical mark readers on the market, several have the capabilities for handling the requirements of the MDT Educational System. Each of the available machines has its own particular sales features and price tag.

There are two major categories of OMRs, those that read sheets of paper and those that read cards. The following are the major concerns in the selection of an optical mark reader:

1. Availability of an OMR already at the school. (Thousands of schools already have adequate hardware. Others will need to replace inadequate scanners.)
2. Capability to handle MDT questions. (See below.)
3. Maximum number of multi-digit questions to be scanned on each answer form. (Present range is from twenty on card readers to fifty on sheet readers; all also offer five-choice questions.)
4. Cost of OMR. ($1,100 for a card scanner; $3,500 for least expensive sheet scanner; scanners at ten, twenty and forty thousand dollars offer different features.)
5. Speed of the scanner in relation to the amount of usage. (A function of volume and school budget.)
6. Automatic form feed verses manual feed. (Some machines can upgrade this feature.)
7. Compatibility with the designated computer. (See Section 4.1)

8. Reliability of mark discrimination. (Extremely important; only some sheet readers offer this feature.)
9. Special features and functions. (Additional software, etc.)
10. Maintenance and service availability. (Ask salesman.)
11. Need for specialized trained operators. (For large OMR models only).
12. Cost of answer forms. (Highly variable depending on type, size and quantity. This is a major consideration.)
13. Physical size. (Minimal problem.)

As of early 1987, the MDT software has been configured to run on five brands of scanners: Cognitronics (all models); National Computer systems (NCS) (all models); Peripheral Dynamics (PDI) card reader CS-27, the Chatsworth 1000 card reader and the HEI card reader. All of these are linked to a microcomputer. At present there are no freestanding scanners that can offer the MDT capabilities.

To assist the potential users of the MDT method, the MDT Corporation is endeavoring to evaluate the various machines as objectively as possible, to indicate the desirable and undesirable features. Actual endorsements of specific machines by the MDT Corporation are not included in this book. Endorsements and other technical information can be obtained by contacting the MDT Corporation (P.O. Box 14, Normal, IL 61761, phone (309) 452-6388).

4.3 Computer Software

There is a variety of computer software for scoring multiple choice tests, but the only programs which also handle the multi-digit long-list answer bank innovations are those developed by the Multi-Digit Technologies Corporation. Because of copyright, patent and trademark protection, any proportedly similar software features from other sources raises questions of illegal infringements. The MDT Corporation intends to license other software producers to incorporate the MDT innovations into their software, once appropriate authorization has been obtained.

This policy reflects several of Paul Anderson's beliefs. First, the enhancement of education is the primary objective. Second, with proper agreements, competing corporations can expand the accomplishments. Third, the MDT innovation is so versatile and powerful for education that it will spread everywhere, requiring expertise in specific market niches. And fourth, the originator will expand on the original MDT multi-digit techniques in ways not revealed in this book.

Those authorized software packages and related products will display the MDT trademark and be advertised as authorized or licensed by Multi-Digit Technologies Corporation. Their availability will be referenced in future editions of this book or in a listing available from the MDT Corporation. Anyone having questions concerning this matter is requested to contact the MDT Corporation.

There are MDT software programs for test scoring, list making and administrative support (test making, grade book, etc.). Product specifications are subject to change without notice, especially because of continual minor enhancements and the addition of major features.

4.3.1 Test Scoring: The multitude of test-scoring features included in the MDT software is nearly the same for the mainframe and the microcomputer versions. The specific features are described in much greater detail in the implementations chapters (five, six and seven) of this book. The various features available include: (1) a complete listing of all student responses as read and recorded from the answer sheet; (2) two to twelve part scores (subtotals) for teacher-specified subdivisions within any given test; (3) variable point values for each part or question; (4) histograms (distribution graphs) of student scores for each part and the grand total; (5) statistical data on the student scores for parts and total, including the mean, median and standard deviation; (6) difficulty and discrimination indexes for each question; (7) item analysis for each question; (8) ability to recall for computer-generated feedback in the item analysis and elsewhere the words and terms associated with each of the code numbers selected by students for their answers; (9) listing of student scores in three different modes: a) alphabetical order by name for a grade book, b) numerical order by identification number for the posting of grades and c) listing in rank order of total points earned on the particular test; and (10) ability to save test scores for entry into a computer-assisted grade book.

4.3.1.1 Mainframe computer programs: The mainframe programs for the MDT capabilities are in two versions called

MDT3 and MDT4. The programs MDT1 and MDT2 were initial prototypes. MDT3, used for three years at Illinois State University, is a control program which calls upon the power and efficiency of the SAS statistical package for the various analyses and printouts. However, MDT3 is rather costly to run in terms of computer time, approximately $12.00-16.00 per test using the ISU pricing levels. The current version is MDT4, a freestanding, self-contained FORTRAN 77 program available for use on almost any mainframe computer. Samples of the output from MDT4 are in the figures in Chapter Seven. This program is available on almost any tape drive format. The recipient school needs to specify the number of tracks, bits per inch, parity or nonparity, labeled or unlabeled and any special characteristics of its computer system. Price information is available from the MDT Corporation. Because of prototype assistance from Illinois State University and the State of Illinois, the cost of these programs is considerably less than what would traditionally be charged for similarly complicated programs developed without institutional support for internal educational purposes. At the same time, these programs are sold commercially because ISU and the State of Illinois do not have the responsibility to maintain, upgrade, advertise or disseminate this testing method.

4.3.1.2 Microcomputer programs: The microcomputer programs are called "MicroMDT" and have a corresponding numerical suffix for each version. As stated in Section 4.1.3 about computer hardware, the appropriate disk operating system (DOS) is essential. MS-DOS for IBM-PC compatibles is the first for which the MDT System is available. The microcomputer program and equipment are less complicated to operate but are slower than the mainframe system when handling many answer sheets and producing numerous printouts. However, because of quick availability and direct control of the microcomputer by the instructor, the actual turnaround time can be considerably faster than when the mainframe versions are used. This is well illustrated by one of the additional features of the MicroMDT program. The "Instant Scoring" feature allows the scoring of tests in the classroom while the students are present. The importance and operations of this feature are discussed in Section 7.8.

Although MicroMDT is a powerful and versatile program, it is modestly priced because of the development support in its initial stages and because of the intent to have this program available to large numbers of instructors. When coupled with the grade book features, the advantages of the MicroMDT become even more evident, as discussed in the implementation chapters. As with the other software from the Multi-Digit Technologies Corporation, MicroMDT is not copy protected, but is copyright material. A statement from ADAPSO about copying software is in the Appendices. Individuals who obtain an unauthorized copy can legalize their use of the program by paying an appropriate copy registration fee to MDT Corporation.

4.3.2 List Making Programs: Since one of the key elements in the proper functioning of the MDT Educational System is the availability of the long-list answer banks, a microcomputer program has been written to facilitate the production of these lists. The "MDT List Maker" program is described in considerable detail in Chapter Five. It is available for use with all of the microcomputers for which the MicroMDT software is available. It is written for mainframe computers because the micro version will create a final file for mainframe purposes. MDT List Maker will edit, alphabetize, merge, number and print the lists of possible answers under the full control of the instructor. From the printout the master lists are made for reproducing the paper copies for student use. Equally important are the computer-readable disc files in the correct formats to be accessed by mainframe and microcomputers. Those files provide improved feedback features whereby the computer knows what word response matches with each numerical response marked on the scannable answer sheet. **Therefore, the importance of the MDT List Maker program should not be underestimated.** It is possible to make lists by hand, but this involves considerably more time and does not have the versatility offered by this unique program. Furthermore, by having the MDT List Maker program, any instructor is able to modify an existing list. By deleting or inserting additional terms and/or having different numberings printed, distinctive lists can be made for different groups of students. **This fingertip control by the teacher insures individualization and virtual customized testing to suit the needs and desires of each instructor.**

4.3.3 MDT Grade Book: To complete the present software portion of the MDT Educational System, a simple but very functional grade book program is included. One of its features is to load directly from the other MDT computer files without key punching the scores. The grade book program can presently accommodate up to two hundred students per course, each with up to twenty scores. Reports can be printed from the grade book.

4.3.4 Upgrades and Enhancements: Future upgrades of the MDT Educational System will include test generating programs which incorporate the unique advantages of MDT multi-digit testing. At present, those programs are being developed along with others that are not yet announced. Upgrades are inevitable in a project as versatile as MDT testing. Waiting for the final feature is futile. Users with maintenance agreements will be among the most favored positions for obtaining enhancements as they become available.

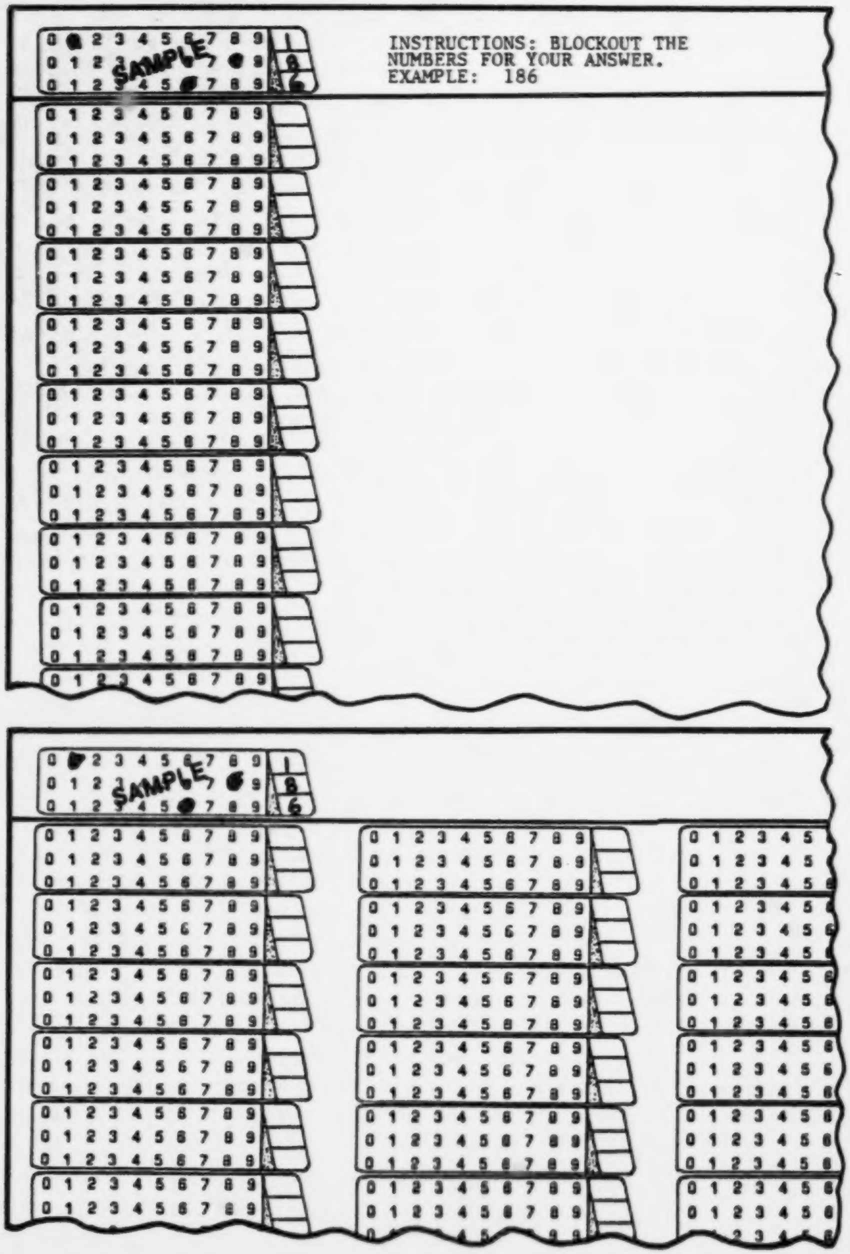
The most up-to-date information concerning any of the MDT software is available from the MDT Corporation. Enhancements, updates and new versions will also be announced in the MDT Bulletin which is sent to all registered users and other parties interested in the MDT system.

4.4 Optional Manual Scoring Techniques

As late as February 1986, the drafts of this book contained the statement: "It is highly unlikely that manual scoring will attain any prominence with regard to the MDT method." Two months later a very operational manual system became available from MDT Corporation for all users without OMR scanner equipment or adequate budgets. The change resulted from research on answer sheet designs and scoring methods. The old hole punching methodology was revived. Multi-Digit Technologies Corporation now offers master copies of different styles of answer sheets for in-school reproduction. One sheet (see answer Form HS1 in Figure 4-2a) has a place for the questions to be printed next to the answer grids, thereby eliminating an extra sheet of paper. Answer sheets with different sized marking grids are available for easier reading by students in the lower grade levels.

A distinctive punch to make holes in the answer key has also been developed (Figure 4-3). It cuts holes in the middle of the sheet as easily as at the edges, but is only the size of a stapler. A punch by IBM for similar pur-

Figure 4-2 Formats for Manually-scored MDT Answer Sheets


INSTRUCTIONS: BLOCKOUT THE NUMBERS FOR YOUR ANSWER.
EXAMPLE: 186
SAMPLE
SAMPLE

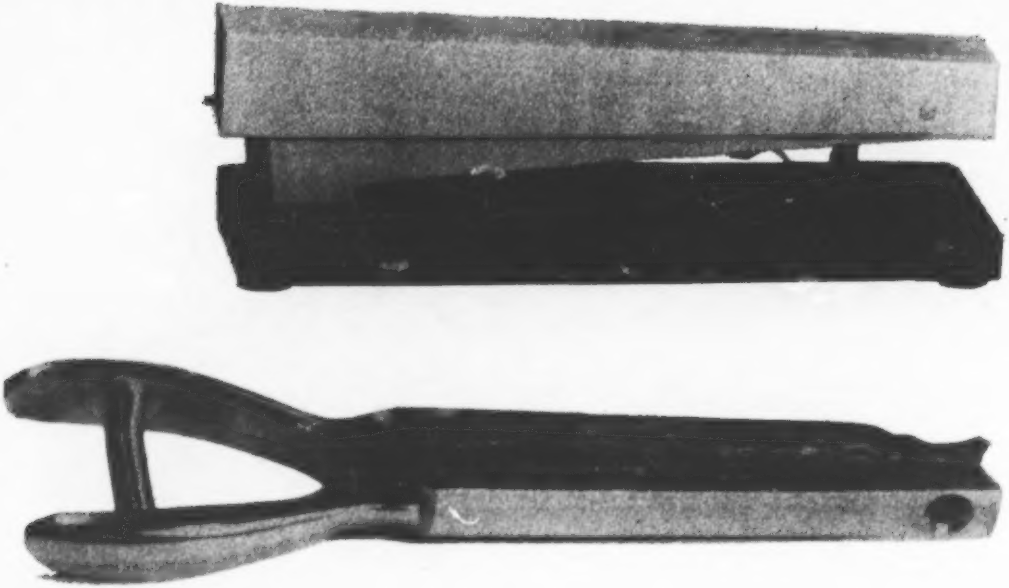
poses has not been manufactured for a decade. The only other long-reach punches now available are expensive and heavy hand-held models (like ticket-taker punches) in which the precise position of the place to be punched is difficult to see. The MDT brand hole punch is designed specifically for making test answer keys. Of course it works for traditional multiple choice questions as well as for the MDT multi-digit questions. Contact the Multi-Digit Technologies Corporation for further information and specific descriptions of products to simplify the manual scoring of all styles of objective tests.

In terms of benefits for education, manual scoring is almost equivalent to the machine-scanned method until feedback is requested. Question writing, list making and test administration in the classroom are identical. The steps to follow are in Chapters Five, Six and most of Seven. However, manual scoring, item analysis, statistical indices, grade book entry, etc., are much slower (and often not done) than the computer assisted feedback. The advantages of a scanner plus computer should not be underestimated. Section 7.5 shows the computer-assisted feedback options. Chapter Ten presents persuasive arguments about how education is improved with scanners. However, where budgets or other factors dictate scoring by hand, the MDT manual method is fully operational.

4.5 Conclusion

The hardware and software components in the MDT Educational System provide an operational environment that allows instructors to do much more than was previously possible with computer-assisted educational measurement. Although the configurations of these components can be highly varied, they all essentially work in the same ways. In general, instructors do not need to have the least concern about these hardware and software issues once a specific configuration has been acquired and operationalized by the school. Teachers are (and should be) much more involved with issues concerning what they can do to improve education and their jobs with the MDT innovations in their classes. The next three chapters provide specific instructions and suggestions to assist the instructors.

Figure 4-3 MDT Hole-Punch for Multi-Digit Testing



Chapter Five

Preliminary Preparations for Giving an MDT Test

5.1 Necessary Materials

It is assumed your school has or will have the appropriate hardware and software (or manual scoring option) as described in Chapter Four. There is only one hardware/software question important to you, the instructor: Is the system operated by a staff member or by each individual teacher?

Considering the financial investment in most scanner systems, there will normally be a person to do or at least coordinate the testing. Meet that person, see the system and find out what support (or limitations) are particular to your school. You, as an individual instructor, would probably become involved in the actual test scoring only in cases involving a microcomputer. The microcomputer operations are especially easy and have step-by-step instructions. You and/or someone under your guidance should learn the procedures to operate the system.

5.2 Selecting The Answer Sheet Or Card

The answer forms for the MDT Educational System can either be cards or sheets similar to those used in machine-scored testing for the past several decades. These are not normal printing jobs and in-school duplication of forms is not yet possible. There are technical specifications of precise page size, special paper, nonreflective inks and positioning of cells for marking. It is important the answer forms meet the specifications of the scanner manufacturers, otherwise the marks made by the students may not be properly interpreted by the scanner and the computer. The Multi-Digit Technologies Corporation and its licensed suppliers guarantee the quality of the MDT answer forms.

Questions that use a long list and multiple digits for each response utilize answer spaces similar to those in Figure 5-1. There are ten cells labeled from 0 to 9 for each digit in the response code. Only a few answer formats are necessary to accommodate tests of different lengths or with special features. This helps reduce costs by having large print runs. The instructor needs to see and understand the answer form selected for a given test situation. Most important is to know the maximum number of each type of question. All of these forms with MDT long-list questions also have places to mark traditional multiple choice and true/false answers. In addition, the feature for the short answer (SA) capabilities (described in Section 7.6) is available on some cards and sheets.

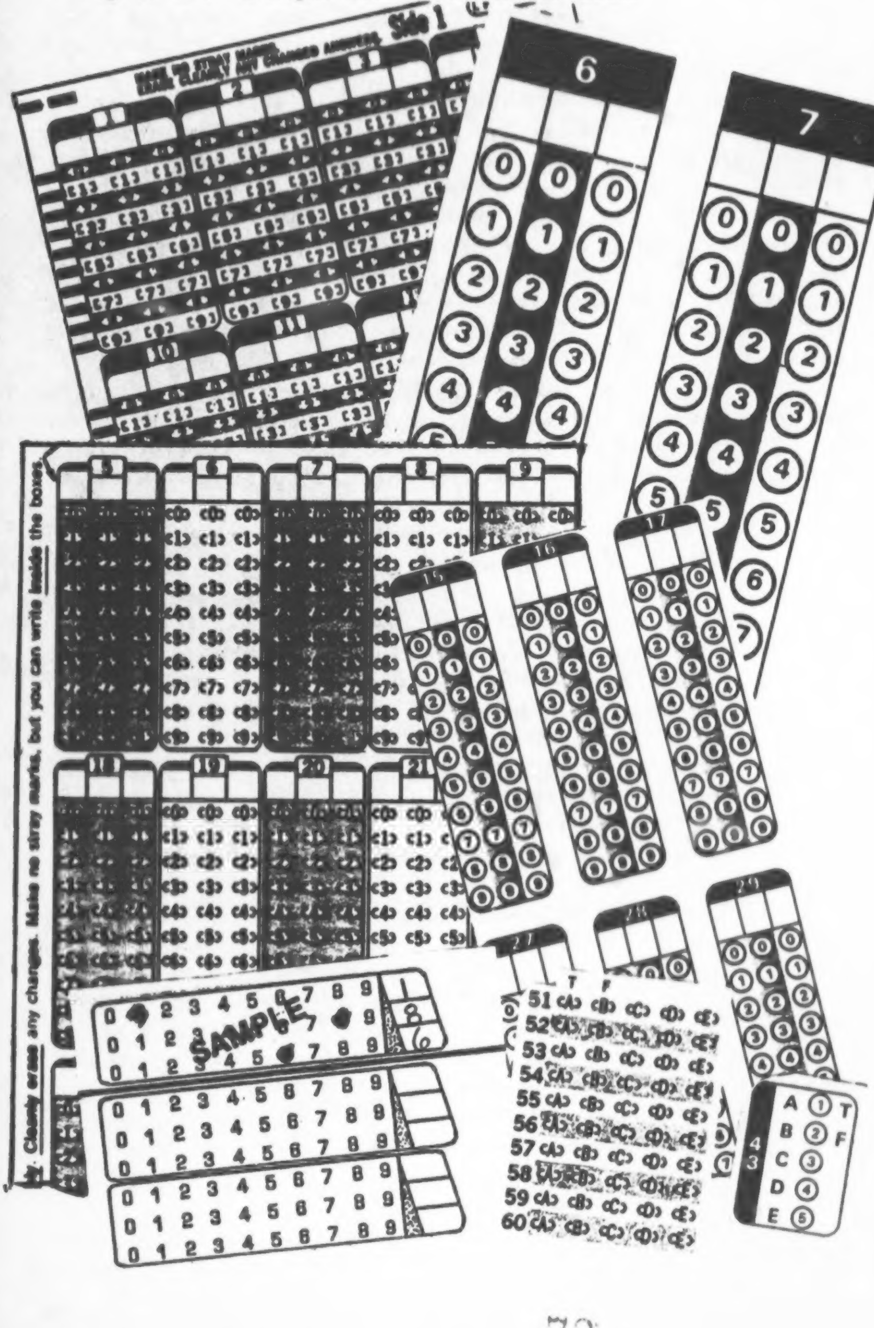
As far as the students are concerned, there are no real differences between the various answer forms. All of the formats are easily understood. Perhaps the most important determining factor concerning selection of either cards or sheets is cost. However, form cost was considered by the institution when decisions were made as to whether it would acquire a card reader or a sheet reader for the hardware system.

Custom-designed cards and sheets are available through the MDT Corporation. A school name or special instructions can also be added to standard forms. Research and development already underway may greatly reduce the cost of having a customized sheet. Alternatively, the development of truly unique answer forms which could be of use to other instructors will receive special consideration. The MDT Corporation will coordinate those developments and publicize them appropriately in the MDT Bulletin.

5.3 Obtaining Long Lists By Purchase, Customizing Or Manual Means

Long lists appropriate for use in the MDT system can be made by instructors or acquired from a variety of sources. Research concerning the nature of the long lists and experience on how to prepare them are presented in the sections which follow. The MDT List Maker program greatly facilitates the production of the long lists. By whatever means, the generation of the lists is considerably easier than it initially appears.

Figure 5-1 Designs for MDT Answer Grids


Side 1
6
7
15
16
17
27
28
29
SAMPLE
Clearly erase any changes. Make no stray marks, but you can write inside the boxes.
T
F
A
B
C
D
E

5.3.1 Preprinted Lists: As of mid-1986 there have been very few subjects covered with an adequate preprinted MDT list. The MDT Corporation has produced a series of lists which are available either in printed form or on floppy diskettes. A partial listing is in Appendix 2. In the future, other lists could be obtained from textbook publishers and professional societies that might provide them for particular areas of expertise. Most publishers and societies already have the terminology in each textbook index or in specialized discipline dictionaries. These organizations often communicate through the mail to specific target markets and memberships. Thus they could disseminate an MDT list as a sales tool or professional service at a very low cost with high benefits. Instructors should not hesitate to ask their textbook suppliers and professional associations about appropriate lists. Furthermore, if an instructor develops a list and is willing to share it with others, a reproducible copy and/or the address for the source of those lists could be sent to the MDT Corporation. List availability will be a key item in the MDT Bulletin.

5.3.2 Manual Lists: When using a photocopied listing from an index of a book, either "white out" or cut off the page numbers with each term. Then give a three-digit code number to each term, preferably at the left-hand side. In order to avoid the inconvenience of cutting out unwanted terms, simply do not put a code number with any terms which are not required. The very first MDT long list by Paul Anderson was made by cutting, gluing and skipping terms (see Figure 2-2.)

Of course, lists can be generated and typed onto a piece of paper for subsequent copying with or without size reductions. Regular word processors can be used, but alphabetizing must be done by the typist. A suitable list has also been made by considering the terms as numbered statements in a computer program written in the BASIC language.

Although these lists can function, they have a major limitation. Their numbered terms cannot be accessed by the computer to obtain the words for the computer-generated feedback about each question. Also, it is difficult to update the manually prepared lists.

5.3.3 Lists Via MDT List Maker: The software program called MDT List Maker is a special purpose word processor. Its numerous but easily performed functions are explained in detail in the Operations Manual which accompanies the software. The unique features performed by simply pressing the function keys include:

a. Alphabetize any list;
b. Renumber any list;
c. Merge (join together) any two lists;
d. Save a list for access by the other programs;
e. Convert a microcomputer disk file into one suitable for mainframe computers; and
f. Print any list so copies can be reproduced for students

It is essential that the MDT List Maker be used to produce any list intended to be accessed by a computer using the MDT Educational System. The length of the records (up to forty-seven letters, numbers or symbols) is standardized for all of the computer programs. This means lists are directly transferable between individuals with diverse hardware configurations with different brands of scanners and computers. The past follies of incompatibilities between computer products must be avoided, otherwise education will suffer. When an instructor changes textbooks, scanners or moves to another school, no prior lists or experience are lost. When a publisher, professional society, government agency or individual teacher makes a list, it can be used by everyone. The technical specifications of the MDT standard for list files are available from the Multi-Digit Technologies Corporation.

5.4 Generating An Entirely New List

The following two pages summarize the sequence of procedures used in generating a new list. The steps do not include the specifics of operating the MDT List Maker program (see Operations Manual) or for making the master layout for multiple copies (see Section 5.10).

Procedure For The Preparation Of Long Lists For MDT Multi-Digit Testing

A. Each interested instructor becomes familiar with the steps below before starting. A brief discussion (approximately fifteen minutes) with anyone familiar with list preparation should clarify any questions.

B. The instructor designates the basic textbook(s) which cover the subject matter in the course. Copies of previously used tests and lectures are also useful.

C. The instructor decides if he/she desires any major divisions within the terms of the subject matter. It is suggested there be no more than four divisions on any final list. Each division is developed as a separate list which can later be merged. Each long list or division should contain at least one hundred and preferably more than two hundred terms for high school and college courses. (Shorter lists can be appropriate for junior high and elementary schools.) These divisions may be made either for blocks of study during the semester or for recurrent themes during the entire semester. An example of a block is whatever is covered in a course during a few weeks. Recurrent themes use the same lists of terms and concepts throughout the semester, as in the case of a history course in which "People" from the entire course are in a list. They could be kept separate from an "Events" division.

D. On photocopies of the index(s) of the selected textbook(s), the instructor (or student worker) marks the key terms using a different color code (or symbol) for each of the major blocks or themes of the list. In general, there is no need to be selective. Terms which might never be used as a correct answer could be important foils (alternatives). Avoid synonyms, phrases and generic words like "big" and "large". Also avoid descriptors like King, River, Theory or Elements.

E. For each of the divisions, type the list of terms into a special microcomputer program (MDT List Maker) which alphabetizes, merges, deletes, duplicates, renumbers and prints the lists. This program is provided with the MDT test scoring software and should be available for use in your school. It can also be purchased separately by those teachers who use manual scoring. When printed, the lists will be in one long column and will look similar to the following:

101 Adams, Abigail
102 Adams, John
103 Adams, John Quincy
104 Anthony, Susan B.
105 Arnold, Benedict
106 Bacon, Nathaniel
107 Barton, Clara
108 Bell, Alexander Graham
109 Calhoun, John C.
110 Columbus, Christopher
111 DaGama, Vasco
112 DeLeon, Juan Ponce
113 Douglas, Stephen A.

F. The instructor reviews the lists to identify any omissions or redundancies, with specific attention given to how the list relates to the course as taught by the teacher. Any additions, deletions or changes may be made easily at this time using MDT List Maker. The long list(s) for a course should be limited to no more than nine hundred ninety-four terms and concepts, plus responses 001 through 005 reserved for the multiple choice questions.

G. When the instructor has approved a complete list (with or without divisions), a final disk file is named and saved. An exact printout is made on the best printer available. Photocopies (with optimal reduced print sizes) are cut and laid out in separate sections with their appropriate titles, all on 11" x 15" paper to be the master sheets. The master layout sheets are further reduced in size so they will fit on one or two sides of 8.5" x 11" sheet of paper. In cases where there is a large number of terms, legal size paper or two (or more) sheets may be used. (More detailed instructions of this step are in Section 5.10.)

H. Send the list for printing, (that is, photoreduced from the master layout sheets) in sufficient quantities for classroom use.

Do not overlook the existence of special subject matter lists which are available to you through your professional societies or in past and present textbooks. For example, a recent article in the Journal of Geography by the National Council for Geographic Education published two highly appropriate lists of core concepts in physical geography. Other good lists may be found in encyclopedias, atlases/-gazeteers and special books available at schools and public libraries.

One series of books which looked very promising but was found to be of little value for making lists was the Book of Lists (Amy Wallace, David Wallechinsky and Irving Wallace. 1971, 1980, 1983, Publisher William Morrow Company, Inc. New York.) Lists in those books tend to be very short and included such unique items as "Eleven authors who had books published by age ten," "The original professions of fifteen Nazi leaders" and "Thirteen secret armies of the CIA." A lead concerning a computer program named "Listmaker" published by the Reader's Digest Education Division was unproductive. Neither contact with a computer store nor a direct inquiry to the Reader's Digest Education Division resulted in obtaining a copy of this program.

5.5 Number Of Terms On A List

It is recommended the lists be as long as possible. Short lists, used either as the entire list or in short divisions for a test, entice students to try to read all the responses. This converts the questions into large multiple choice items, disrupting the intent of the MDT method. Students start requesting excessive amounts of time to allow them to read through the lists of 100 to 150 terms. Early experiences with the first World Geography course give no reason to suspect that subdivided lists have any advantages. The merging of the lists of Cities, Terrain Features, Political Units and Water Features was very effective. It also eliminated the situation where students selected an appropriate term such as Mississippi from the rivers list when in fact they were asked to select Mississippi from the list of political units.

It is important to note that the terms on a list do NOT need to be viable alternatives. In fact, even terms from other disciplines could be used, although made-up jibberish should probably be avoided. It makes no difference that "Fillibuster" would not be a logical answer as the name of the third President of the United States. The objective is to have a list so long that students have difficulty searching through it attempting to recognize the correct answer.

To avoid confusion, do not include adjective, adverb and plural forms of the terms. Unless there is a specific reason and if the instructor assumes the responsibility to inform his/her class, the lists should not contain any of these modified forms of key words. In keeping with the previous example, the term for the Mississippian Geological Period should still be coded in as the term Mississippi.

Although long lists are desirable, short lists do function. Beginning users of the MDT method might not have sufficient time, experience or inclination to make a list of hundreds. Instead, a list with forty to ninety terms could be used for a test or two. Students will treat the questions as "matching" and will read all of the terms searching for answers. Instructors will get a feel for the MDT method. Short lists are really an interim method. The real power of MDT multi-digit testing is in lists that are too long to be read.

5.6 Numbering The Terms

Counting the response 000, there are one thousand alternatives with the three-digit answer sheet. For most courses, this number should be sufficient. However, the choice of how to number is totally at the discretion of the individual instructor. Here are a few useful suggestions.

5.6.1 Reserved Numbers 000-010 and 999: Number 000, which is also equivalent in the computer's circuitry to a blank or nonresponse, should not be used for a specific answer. It should only indicate a nonresponse or a blank. The number 999 is generally reserved for the response "No reasonable answer is found on the list(s)." The numbers 001 through 010 should not be used because they are the response codes for a standard multiple choice question.

5.6.2 Reserved Numbers 011-099: If the list of terms is shorter than 900, it is desirable to start the numbering of the printed list with the number 101. The purpose of this is to avoid confusion concerning the leading (left hand) zero for numbers under 100. For some of the computer software for test scoring, the presence or absence of a mark for a leading zero could mean the difference of scoring the answer as correct or incorrect. (See Chapter Seven on instructions to students.) Furthermore, by keeping the first one hundred choices open, the instructor retains the option of inserting into the test itself some smaller lists. For example, matching-style questions could include course content not covered in the printed long list. This flexibility is of great advantage to the teacher and serves to inform the students that lecture topics relating to current events or class discussions could also be included in the testable materials without requiring a new printed list.

One further advantage of keeping the first one hundred numbers clear is that if the list actually goes over the one hundred items, it would be possible to have additional items numbered from 1001 through 1099 and also from 2001 through 2099 to provide an additional two hundred terms in the listing. The leading digits (1 and 2 in 1000 and 2000) would not be encoded onto the sheet, but the other numbers from 001 through 099 could be used repeatedly. In those instances, the students only have a one in one hundred chance of guessing the correct answer. The major disadvantage is that there is no longer only one discrete term or phrase for a given code number. Therefore, the computer is unable to offer a discrete correct response for each of two or three duplicate usages of each code number.

5.7 Actual Numerical Answers

There is no need to make a list of actual numerical answers for calculation questions, as explained in Section 6.3.4. Even if a numerical answer (such as 186 pounds or dollars) is the same as the code number 186 for a term on the long list, it is immaterial to the testing process. The student did not search to find the term encoded 186 when he/she was calculating the numerical value. In addition, during the scoring phase the computer is technically blind to terms which are associated with each code number. Therefore, the computer interprets the number 186 as the correct answer. The only place where there is some contusion is on the computer generated printout where the code number 186 will have the word answer written next to it. However, the teacher and the students should be well aware of this fact, knowing the question required an actual number, not the words which are encoded by the number.

When a less precise numerical value other than a specific three-digit number is desired, code numbers can be assigned to a range of values or specified time periods. Several examples are given in Figure 5-2. In these cases, everything is treated exactly the same as when words are associated with each code number. (Of course, the instructor or written instructions should inform the students to refer to a designated list of dates, ranges, etc. when selecting the code numbers.)

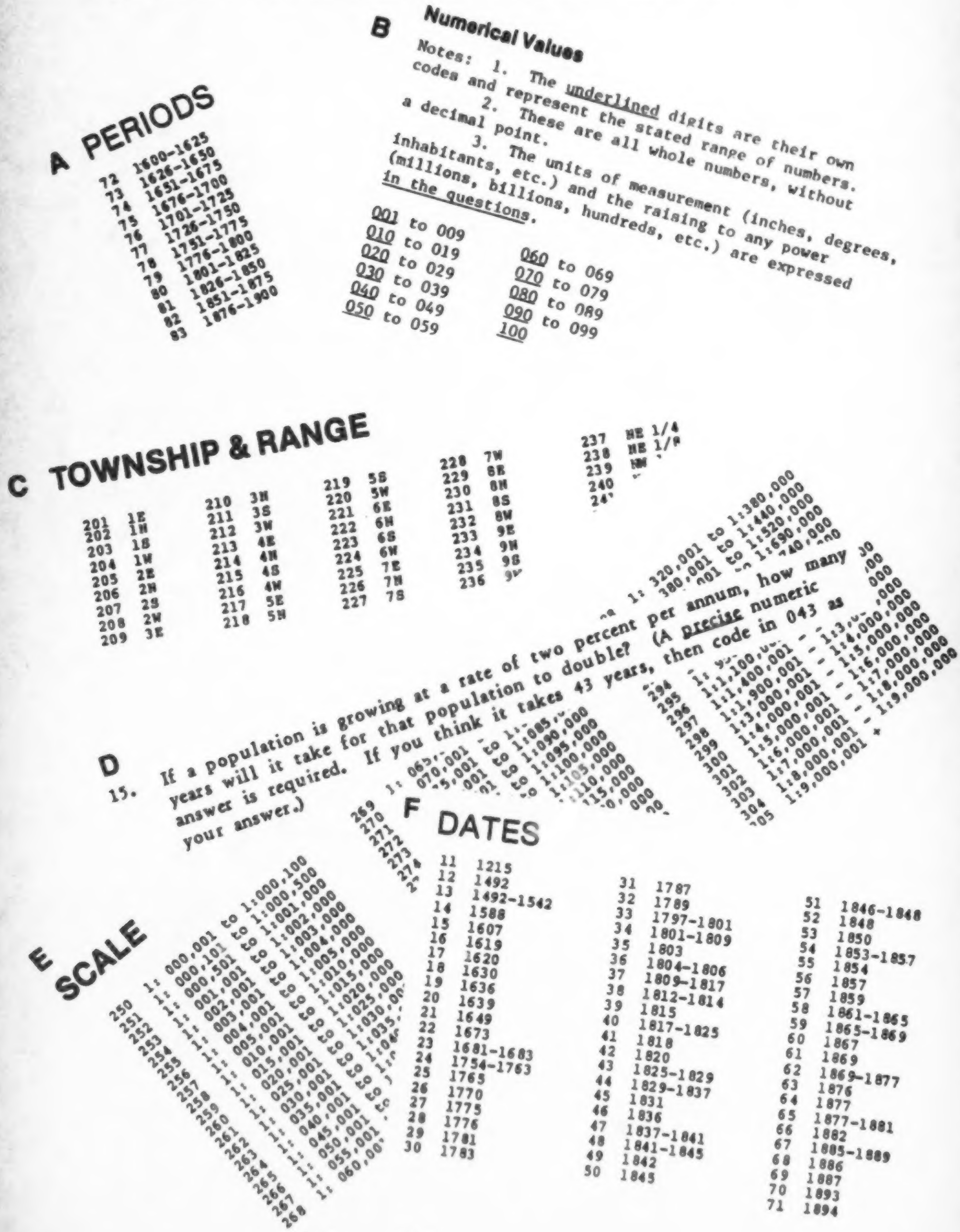
When you make your test, be aware that the high precision and ultra-objective nature of computer scoring does not allow for flexibility, as in the case of a miscalculation although the student used the otherwise correct problem solving techniques. Because of the great potential concerning questions which have actual numeric answers, this topic is discussed again in Sections 6.4.4 and 11.5.

5.8 Other Characteristics Of Lists

5.8.1 Capital Letters: In order to avoid any confusion both for the student and the computer, a general rule in the preparation and use of the long lists is that the first letter of each name must be capitalized. Although it is technically not correct to capitalize the first letter of names such as "de Leon", the noncapitalization could be a reminder to the student concerning the correct answer. In addition, not capitalizing would cause the MDT List Maker program to place the noncapitalized name at the end of all the names which begin with the capital letter "D". (One of the characteristics of alphabetization in most computer languages is that upper case letters are grouped together prior to lower case letters.) Likewise, underlinings, italics and quotation marks around names in the long list should be avoided. The use of lower case letters for the remainder of the name or term is preferred to improve readability of words. However, MDT List Maker will also produce all upper case letters if desired.

5.8.2 One List for Many Tests: It is often overlooked by people who are just learning about the MDT multi-digit test method that any list can be used repeatedly for many tests and for many questions. There is no need to prepare a separate answer bank for each test unless the instructor so desires or is making major revisions in the list(s) previously used. Thus, the lists only need to be

Figure 5-2 MDT Methods for Numerical Responses



A PERIODS

72	1600-1625
73	1626-1650
74	1651-1675
75	1676-1700
76	1701-1725
77	1726-1750
78	1751-1775
79	1776-1800
80	1801-1825
81	1826-1850
82	1851-1875
83	1876-1900

B Numerical Values

Notes: 1. The underlined digits are their own codes and represent the stated range of numbers.

2. These are all whole numbers, without a decimal point.

3. The units of measurement (inches, degrees, inhabitants, etc.) and the raising to any power (millions, billions, hundreds, etc.) are expressed in the questions.

001 to 009
010 to 019
020 to 029
030 to 039
040 to 049
050 to 059
060 to 069
070 to 079
080 to 089
090 to 099
100

C TOWNSHIP & RANGE

201	1E
202	1N
203	1S
204	1W
205	2E
206	2N
207	2S
208	2W
209	3E
210	3N
211	3S
212	3W
213	4E
214	4N
215	4S
216	4W
217	5E
218	5N
219	5S
220	5W
221	6E
222	6N
223	6S
224	6W
225	7E
226	7N
227	7S
228	7W
229	8E
230	8N
231	8S
232	8W
233	9E
234	9N
235	9S
236	9W
237	NE 1/4
238	NE 1/
239	NW
240	
24	

1: 320,001 to 1:380,000
380,001 to 1:440,000
001 to 1:520,000
1:690,000

D

15. If a population is growing at a rate of two percent per annum, how many years will it take for that population to double? (A precise numeric answer is required. If you think it takes 43 years, then code in 043 as your answer.)

1: 065,001 to 1:085,
070,001 to 1:090,000
5,001 to 1:095,000
001 to 1:100,000
to 1:105,000
1:110,000
115,000
0,000

294
295
296
297
298
299
300
301
302
303
304
305

1: 9
1:1,100,0
1:1,400,001 -
1:1,900,001 - 1:3,0
1:3,000,001 - 1:4,000,000
1:4,000,001 - 1:5,000,000
1:5,000,001 - 1:6,000,000
1:6,000,001 - 1:7,000,000
1:7,000,001 - 1:8,000,000
1:8,000,001 - 1:9,000,000
1:9,000,001 +

E SCALE

250	1: 000,001 to 1:000,100
251	1: 000,101 to 1:000,500
252	1: 000,501 to 1:001,000
253	1: 001,001 to 1:002,000
254	1: 002,001 to 1:003,000
255	1: 003,001 to 1:004,000
256	1: 004,001 to 1:005,000
257	1: 005,001 to 1:010,000
258	1: 010,001 to 1:015,000
259	1: 015,001 to 1:020,000
260	1: 020,001 to 1:025,000
261	1: 025,001 to 1:030,00
262	1: 030,001 to 1:035,
263	1: 035,001 to 1:04
264	1: 040,001 to 1:
265	1: 045,001 to
266	1: 050,001 to
267	1: 055,001
268	1: 060,00

269
270
271
272
273
274

F DATES

11	1215
12	1492
13	1492-1542
14	1588
15	1607
16	1619
17	1620
18	1630
19	1636
20	1639
21	1649
22	1673
23	1681-1683
24	1754-1763
25	1765
26	1770
27	1775
28	1776
29	1781
30	1783
31	1787
32	1789
33	1797-1801
34	1801-1809
35	1803
36	1804-1806
37	1809-1817
38	1812-1814
39	1815
40	1817-1825
41	1818
42	1820
43	1825-1829
44	1829-1837
45	1831
46	1836
47	1837-1841
48	1841-1845
49	1842
50	1845
51	1846-1848
52	1848
53	1850
54	1853-1857
55	1854
56	1857
57	1859
58	1861-1865
59	1865-1869
60	1867
61	1869
62	1869-1877
63	1876
64	1877
65	1877-1881
66	1882
67	1885-1889
68	1886
69	1887
70	1893
71	1894

prepared one time for use with numerous questions and tests.

During the initial stages of learning to use the MDT method self-made lists often could bear some refinement. The MDT List Maker program is very helpful for such changes. However, care in list preparation is highly desirable because any omissions could influence future possible questions. Alternatively, the teacher could utilize the following options: "999, No reasonable answer is on the list(s);" b) having a mini-list printed in the test (see Section 5.6.2); or c) asking questions in the multiple choice section although they could have been in the MDT long-list mode if the terms had been on the list.

5.8.3 Plastic Page Protectors: Because lists can be used repeatedly, it is desirable to protect them from marks by students. The simplest way is to insert each long list sheet into an 8.5" x 11" plastic page protector available commercially for approximately seven cents each. The students are still able to see both sides of the list, but no marks can be made. The only criticism concerning the use of plastic protectors is the glare from the reflection of the lights. The simplest solution is to announce that any student encountering such a problem is at liberty to remove the sheet from the protector during the test. In the past, fewer than one percent of the students have removed the sheet.

5.8.4 Alphabetizing the List: **THERE MUST BE AN INHERENT ORDER WITHIN THE ITEMS ON THE LIST.** The most logical order is to alphabetize them. Some disciplines might utilize a different ordering system such as atomic weights or biological orders. The important thing is the student has means of going directly to a specified answer once he/she has recalled the answer. An unordered list would be like the hunt through a haystack for the proverbial needle. Unnecessary searching for a known answer would defeat the purposes and objectives of the MDT long-list method.

5.8.5 Ambiguous Answers: Caution must be exercised in cases where two or more terms on a list could be an answer to the same question. One solution is to eliminate all but one of the similar terms. Another is to give the same code number to both terms even though in one place the code numbers will be out of order. On printouts from the MDT List Maker program the change of one number would have to be done manually (cut and glued) before the final reproduction of the copies. An additional option which has been used successfully is to "white out" the code number of one of the synonyms and to note after that term that the student should either refer to the alternative term elsewhere on the list or use a code number provided. For example:

(white) Prairie State (see Illinois); or
(white) Prairie State (use code 243)

The fact one number has been whited out is of no consequence to the testing method nor to the computer system. Since the number does not appear on the list the students use, it should never be encoded onto an answer form.

In spite of diligent efforts, students do continue to find reasonable synonyms in a list. These should be evident to the instructor when reviewing the computer-generated printout which contains the word responses along with each of the code numbers. For example, the United Kingdom and England are two different political units, but a poor question might merit either response as a correct answer. Allow points for the students answers, then for future use modify the list or the question to avoid synonym problems.

5.8.6 Two or More Versions of the Same Lists: In cases where there are large numbers of students taking the same test in crowded surroundings, it is often desirable and easily possible to have two or more versions of the same list. To obtain different numbers on the listed terms, renumbering can be accomplished with the MDT List Maker program by adding or deleting one term or starting with a different number. Although the student answer sheets must be graded separately according to which long list they used, the student scores and statistical results will be directly comparable. To avoid administrative confusion, be sure to mark every list version in a distinctive way. For example, place a single letter or symbol in a corner of each master sheet so it will be printed clearly to specify the version of each copy. It is highly desirable that all printed lists are clearly labeled to identify the matching computer disk files. When a semester or two have passed and alternative versions of lists exist for a course, the importance of clear labels for each version is very evident.

5.9 Making Multiple Copies Of Long Lists

5.9.1 Deterioration of Copy Quality: A sure way to obtain student complaints is to provide illegible copies of the lists. Copies of copies of copies lead to what is known as generation deterioration (see Figure 5-3). Therefore, the best possible copy of every list should be kept separate and used only for making additional copies. The MDT Corporation offers reproducible master sheets in several formats to minimize the deterioration of copy quality.

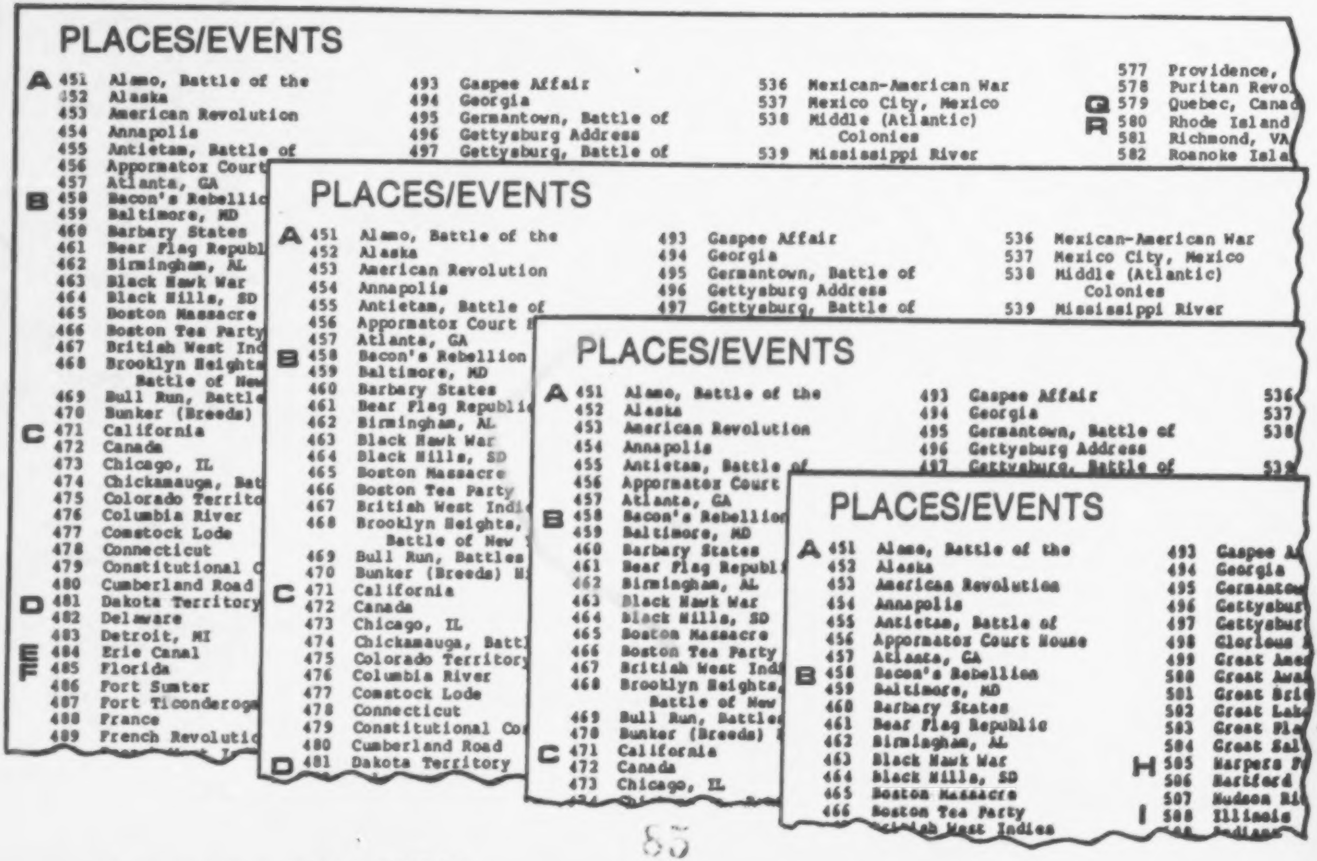
5.9.2 Copies Too Small or Too Large: In the vast majority of cases, there is no need to reproduce the long lists at the size of regular typewriter print. (Figure 5-4 shows common reduction sizes.) The disadvantage associated with that size of print is that it takes many more pages to include the nine hundred ninety-nine options. Those extra pages not only cost more money to reproduce in multiple quantities, but also make it more difficult for the student taking the test. Flipping between pages hunting for M's after looking for something in the D's on the previous question can be frustrating. Fortunately, there is an easy solution in the form of simple, low cost photocopy reductions, as described below.

For students with impaired vision, copies should be made as large as necessary using large sheets of photocopy paper and/or providing a magnifying glass for those students.

5.10 Final List Preparation

Whether obtained from hand generation and typing or from a computer printout using the MDT List Maker program, the instructor starts with one long and continuous column listing of the appropriate terms and their code numbers. In order to produce lists similar to the ones seen in Figures 1-1, 1-3 and 8-1 in this book, the procedures are as follows:

1. Make a photocopy reduction of the pages, preferably onto long (legal size) sheets. Use the seventy-eight percent (of original size) common reduction or the sixty-five percent reduction which will yield a smaller final size (see Figure 5-4). SAVE THE ORIGINAL FULL SIZE LISTING IN



PLACES/EVENTS

A 451 Alamo, Battle of the
452 Alaska
453 American Revolution
454 Annapolis
455 Antietam, Battle of
456 Appomattox Court
457 Atlanta, GA
B 458 Bacon's Rebellio
459 Baltimore, MD
460 Barbary States
461 Bear Flag Republ
462 Birmingham, AL
463 Black Hawk War
464 Black Hills, SD
465 Boston Massacre
466 Boston Tea Party
467 British West Ind
468 Brooklyn Heights
Battle of New
469 Bull Run, Battle
470 Bunker (Breeds)
C 471 California
472 Canada
473 Chicago, IL
474 Chickamauga, Bat
475 Colorado Territo
476 Columbia River
477 Comstock Lode
478 Connecticut
479 Constitutional C
480 Cumberland Road
D 481 Dakota Territory
482 Delaware
483 Detroit, MI
E 484 Erie Canal
F 485 Florida
486 Fort Sumter
487 Fort Ticonderoga
488 France
489 French Revolutio

493 Gaspee Affair
494 Georgia
495 Germantown, Battle of
496 Gettysburg Address
497 Gettysburg, Battle of

536 Mexican-American War
537 Mexico City, Mexico
538 Middle (Atlantic)
Colonies
539 Mississippi River

577 Providence,
578 Puritan Revo
Q 579 Quebec, Canad
R 580 Rhode Island
581 Richmond, VA
582 Roanoke Isla

PLACES/EVENTS

A 451 Alamo, Battle of the
452 Alaska
453 American Revolution
454 Annapolis
455 Antietam, Battle of
456 Appomattox Court H
457 Atlanta, GA
B 458 Bacon's Rebellion
459 Baltimore, MD
460 Barbary States
461 Bear Flag Republic
462 Birmingham, AL
463 Black Hawk War
464 Black Hills, SD
465 Boston Massacre
466 Boston Tea Party
467 British West Indi
468 Brooklyn Heights,
Battle of New
469 Bull Run, Battles
470 Bunker (Breeds) H
C 471 California
472 Canada
473 Chicago, IL
474 Chickamauga, Battl
475 Colorado Territory
476 Columbia River
477 Comstock Lode
478 Connecticut
479 Constitutional Co
480 Cumberland Road
D 481 Dakota Territory

493 Gaspee Affair
494 Georgia
495 Germantown, Battle of
496 Gettysburg Address
497 Gettysburg, Battle of

536 Mexican-American War
537 Mexico City, Mexico
538 Middle (Atlantic)
Colonies
539 Mississippi River

PLACES/EVENTS

A 451 Alamo, Battle of the
452 Alaska
453 American Revolution
454 Annapolis
455 Antietam, Battle of
456 Appomattox Court
457 Atlanta, GA
B 458 Bacon's Rebellion
459 Baltimore, MD
460 Barbary States
461 Bear Flag Republ
462 Birmingham, AL
463 Black Hawk War
464 Black Hills, SD
465 Boston Massacre
466 Boston Tea Party
467 British West Indi
468 Brooklyn Heights,
Battle of New
469 Bull Run, Battles
470 Bunker (Breeds)
C 471 California
472 Canada
473 Chicago, IL

493 Gaspee Affair
494 Georgia
495 Germantown, Battle of
496 Gettysburg Address
497 Gettysburg, Battle of

536
537
538
539

PLACES/EVENTS

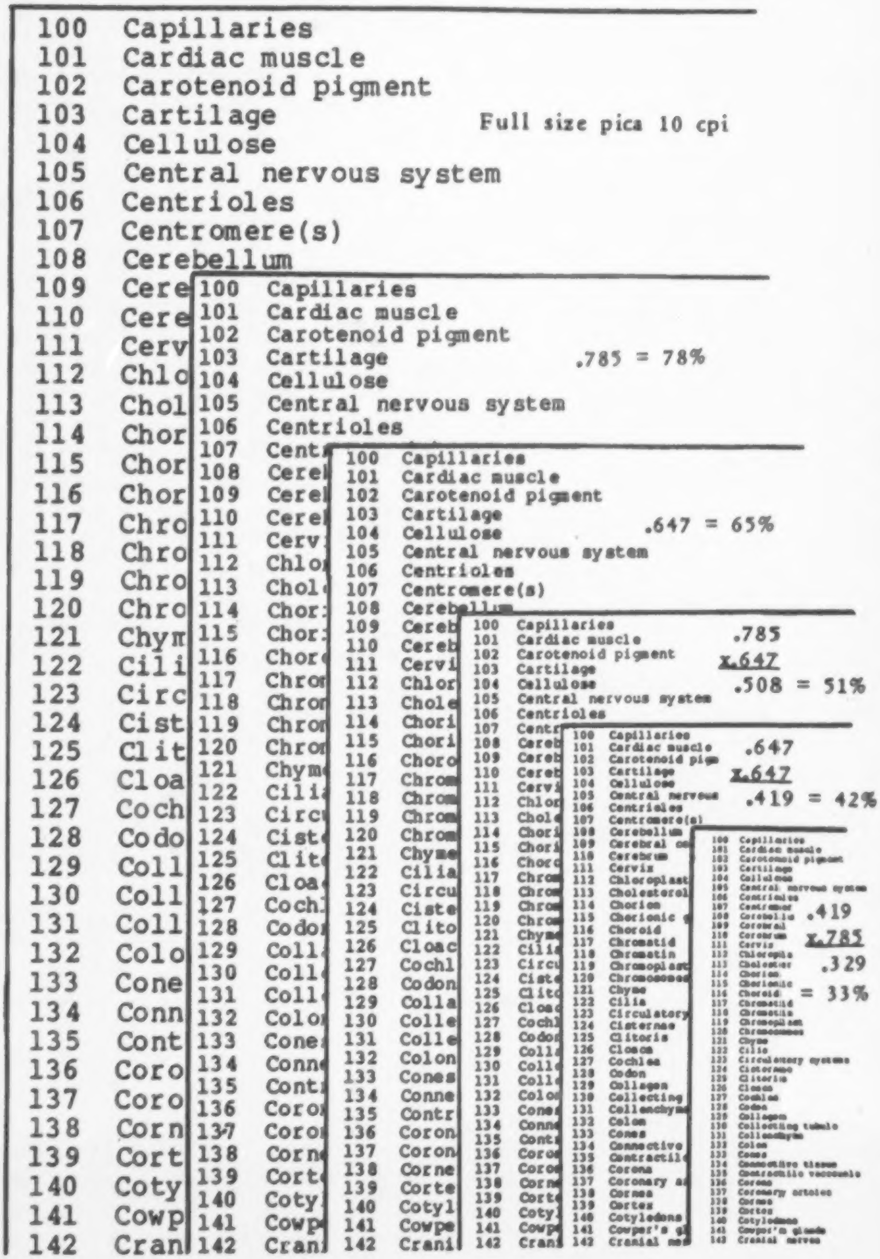
A 451 Alamo, Battle of the
452 Alaska
453 American Revolution
454 Annapolis
455 Antietam, Battle of
456 Appomattox Court House
457 Atlanta, GA
B 458 Bacon's Rebellion
459 Baltimore, MD
460 Barbary States
461 Bear Flag Republic
462 Birmingham, AL
463 Black Hawk War
464 Black Hills, SD
465 Boston Massacre
466 Boston Tea Party
British West Indies

493 Gaspee A
494 Georgia
495 Germanto
496 Gettysbur
497 Gettysbur
498 Glorious
499 Great Ame
500 Great Awa
501 Great Bri
502 Great Lak
503 Great Pla
504 Great Sal
H 505 Harpers F
506 Hartford
507 Hudson Ri
I 508 Illinois

Figure 5-3 Generation Deterioration of Copy Legibility

BEST COPY AVAILABLE

Figure 5-4 Common Reduction Sizes for MDT Long Lists



100 Capillaries
101 Cardiac muscle
102 Carotenoid pigment
103 Cartilage
104 Cellulose
105 Central nervous system
106 Centrioles
107 Centromere(s)
108 Cerebellum
109 Cere
110 Cere
111 Cerv
112 Chlo
113 Chol
114 Chor
115 Chor
116 Chor
117 Chro
118 Chro
119 Chro
120 Chro
121 Chym
122 Cili
123 Circ
124 Cist
125 Clit
126 Cloa
127 Coch
128 Codo
129 Coll
130 Coll
131 Coll
132 Colo
133 Cone
134 Conn
135 Cont
136 Coro
137 Coro
138 Corn
139 Cort
140 Coty
141 Cowp
142 Cran

Full size pica 10 cpi
.785 = 78%
.647 = 65%
.785
x.647
.508 = 51%
.647
x.647
.419 = 42%
.419
x.785
.329
= 33%

BEST COPY AVAILABLE

A FOLDER; YOU MAY WANT TO USE IT AGAIN LATER. When photoreducing, allow the end of each sheet to overlap slightly with those on the next sheet of photocopies. This will avoid accidently omitting a few items and will make it easier for the final mount up. Note: If your list is short and the final letters are to be no smaller than what can be done with a single reduction, steps one and two can be eliminated.

2. Cut the photoreduced long lists into columnar strips and glue them together end to end. Rubber cement or artist glue stick works best because they do not wrinkle the paper. If available, use a light table to allow you to see the items superimposed on each other. Simply line them up with a ruler or graph paper and glue them to each other in one long strip. (A window or translucent material, even a large flat Tupperware item makes a reasonable light tables.)

3. The entire length of the long list must be divided at appropriate spots to match the number of columns (usually four or five) available to you on the paste up sheet. Remember that a final list could have two sides; use a separate sheet for each side. The paste up should be on a large piece of paper measuring 11" x 15" (or 11" x 17" if that size is available.) Check early with the photocopy shop to be sure your paste up is the right size to produce the final reduced copies.

4. This large page is the master layout sheet which will be used to make the reduced copies required for your class. Onto the master sheet you can place any titles, labels, borderlines or artwork you desire to reproduce on each of the copies the students will use. The addition of press-type index letters (see Figure 1-3) is very useful for students.

Note: If your first attempt is less than perfect, do not be discouraged. (Look at Figure 2-2 and see how poor the very first MDT long list was.) As the MDT method is utilized, you will possibly desire some list modifications, perhaps for your second test or possibly within a couple of years. At that time, you may improve the appearance of your revised list. As the MDT method becomes more widely used, individuals with artistic or layout talent will be able to prepare these lists in a professional looking manner at an extremely low cost. Good students in art or industrial design at your school might be utilized to assist in the layout of your long lists.

5.11 Supplementary Materials

The MDT innovation opens new avenues to use standard supplementary material easily. Do not overlook the vast amount of potential supplementary material that could be used appropriately with the MDT multi-digit method of testing. Pictorial/graphic representations of part of the course content might include maps, diagrams from the textbook, slides on a screen, etc. Some samples of various supplementary materials are given in Figure 5-5 (four pages). Diagrammatic materials available from government and academic sources could greatly increase the versatility of your testing. Figures in textbooks are also good sources. A map example is in Figure 1-4. The labels and written information are usually replaced by numbers. Simply "white out" the words and insert numbers. Literally hundreds of questions can be generated from a single diagram. (Section 6.5 discusses question generation using supplementary materials.)

Other supplementary pages could include items which must be studied to answer the question(s). For example, an American Literature teacher could have a sheet with passages from a novel, while a History instructor could ask students to interpret a document. Some could require high order thinking to arrive at the correct answers. Most science and mathematical tests could make very good use of the supplemental pages in conjunction with the MDT long-list testing method.

5.12 Conclusion

Some of the suggestions in the next two chapters might also be considered preliminary preparation. That will depend on the school situation. After reading those chapters and using the MDT methods in your classes, you might have some suggestions of additional tips for other instructors. Please send them to the MDT Corporation. They could be disseminated in the MDT Bulletin and future editions of this book.

Figure 5-5a Examples of Supplementary Pages: Geography
(See also Figure 1-4: Map)

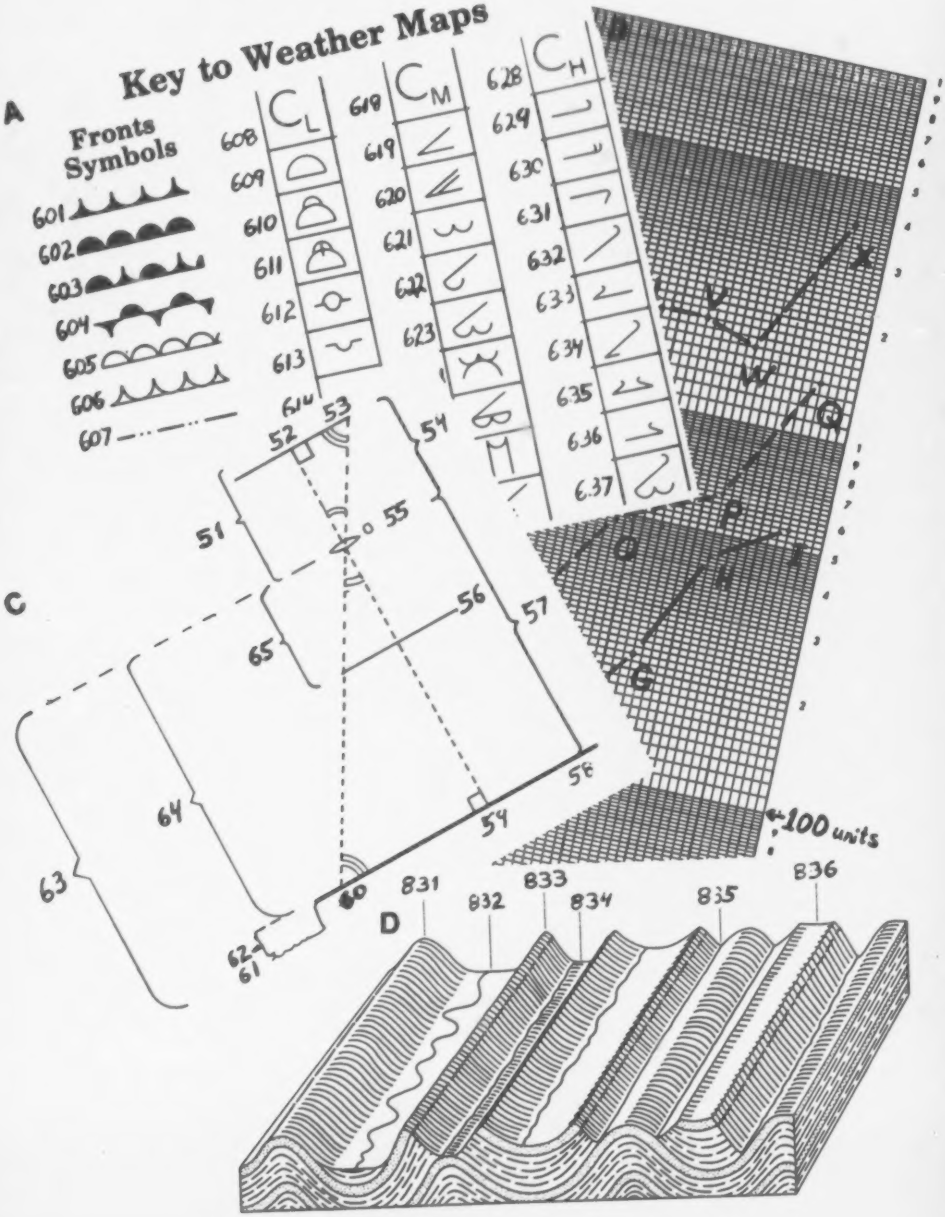
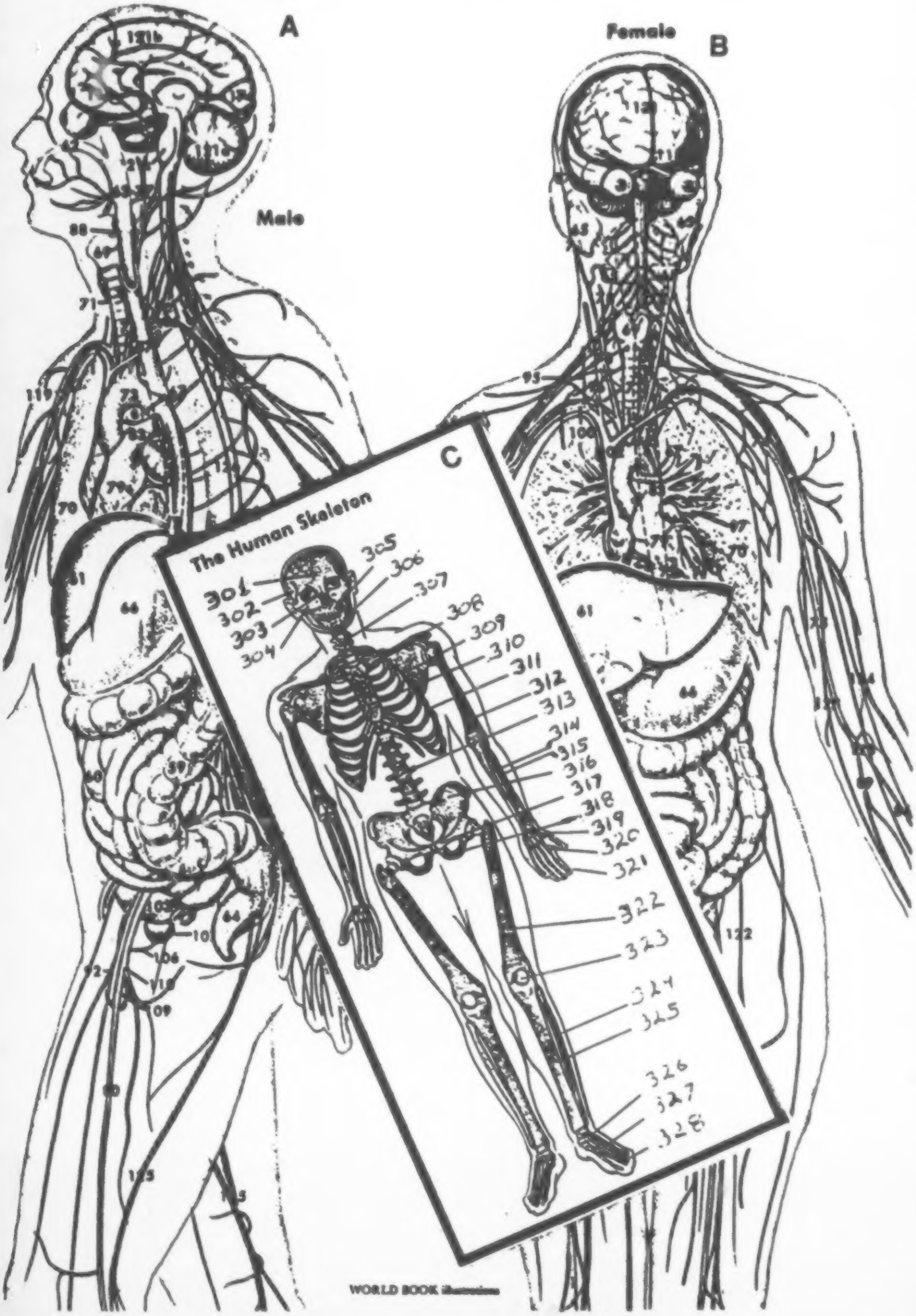
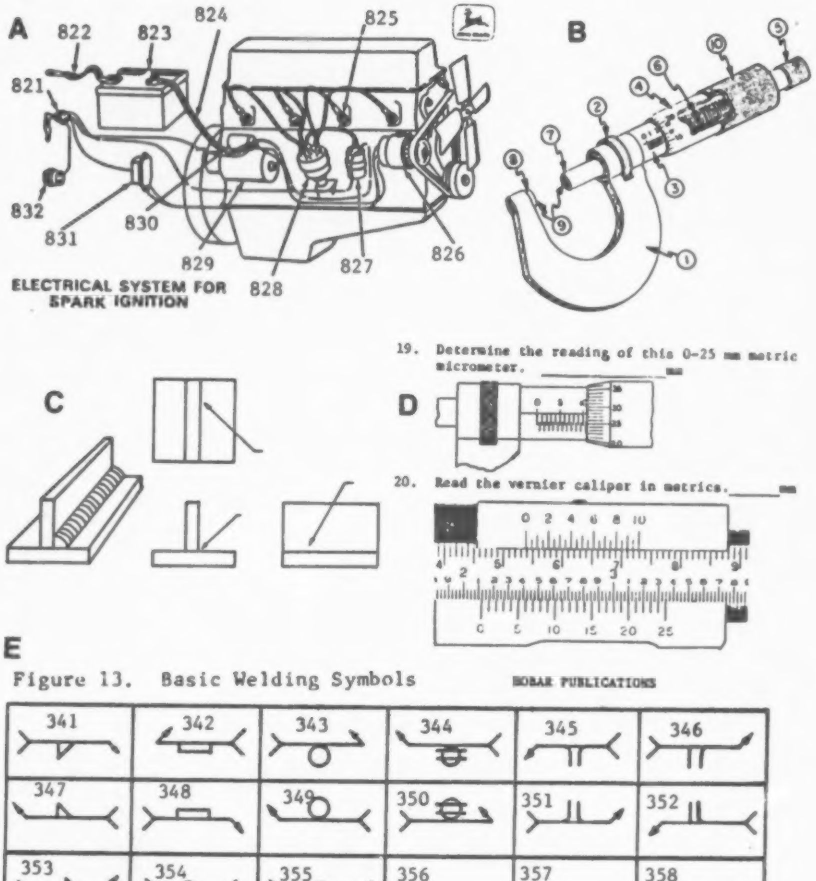

A
Key to Weather Maps
Fronts Symbols
601
602
603
604
605
606
607
C_L
608
609
610
611
612
613
614
C_M
618
619
620
621
622
623
C_H
628
629
630
631
632
633
634
635
636
637
B
X
V
W
Q
P
O
H
I
G
100 units
C
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
D
831
832
833
834
835
836

Figure 5-5b Examples of Supplementary Pages: Anatomy


A
Male
B
Female
C
The Human Skeleton
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
121b
88
71
119
70
61
66
60
59
64
101
106
92
109
95
100
97
122

WORLD BOOK illustrations

Figure 5-5c Examples of Supplementary Pages: Mechanics/Hardware


A
822
823
824
825
821
832
831
830
829
828
827
826
ELECTRICAL SYSTEM FOR SPARK IGNITION
B
①
②
③
④
⑤
⑥
⑦
⑧
⑨
⑩
C
D
0 2 4 6 8 10
4 5 6 7 8 9
0 5 10 15 20 25

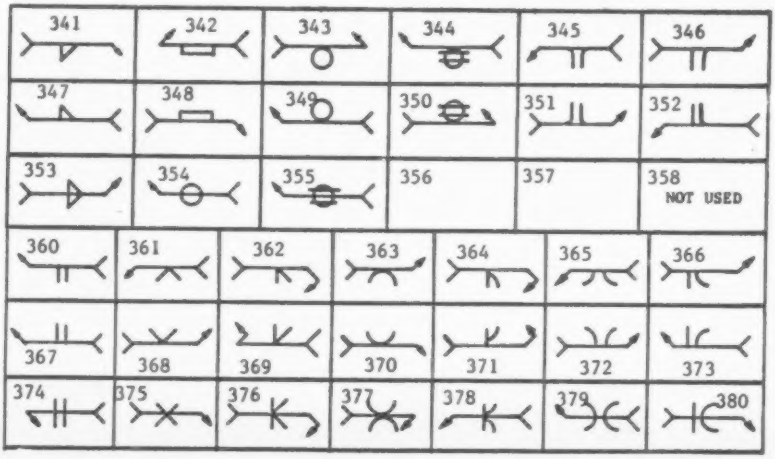
19. Determine the reading of this 0-25 mm metric micrometer. ________mm

20. Read the vernier caliper in metrics. ______mm

E

Figure 13. Basic Welding Symbols

HOBAR PUBLICATIONS


341
342
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344
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346
347
348
349
350
351
352
353
354
355
356
357
358 NOT USED
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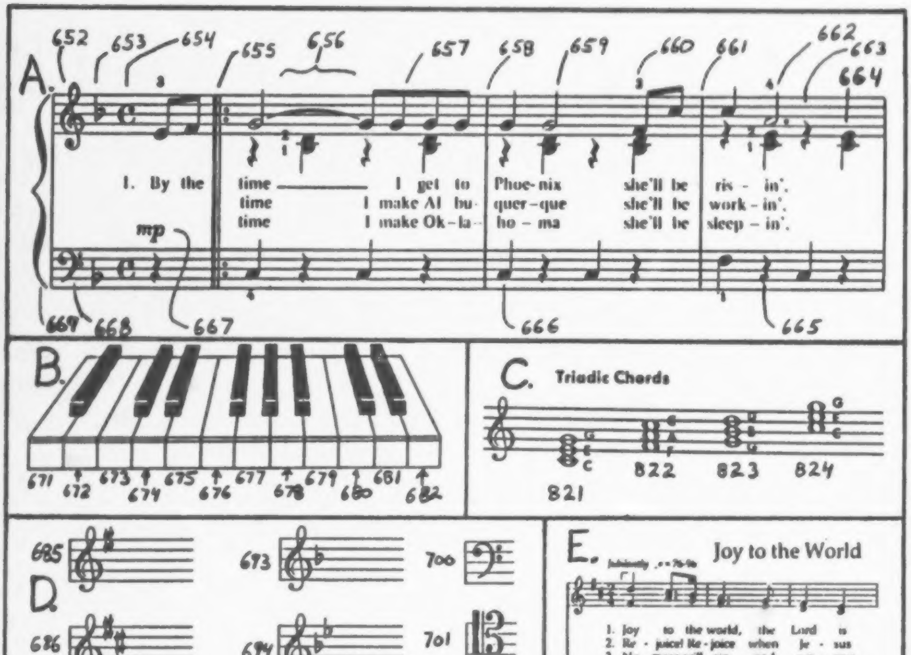
Figure 5-5d Examples of Supplementary Pages: Music


A.
652
653
654
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656
657
658
659
660
661
662
663
664
1. By the time ——— I get to Phoe-nix she'll be ris - in'.
time I make Al bu- quer-que she'll be work - in'.
time I make Ok-la- ho - ma she'll be sleep - in'.
mp
669
668
667
666
665
B.
671
672
673
674
675
676
677
678
679
680
681
682
C.
Triadic Chords
821
822
823
824
D.
685
686
687
688
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
E.
Joy to the World
1. Joy to the world, the Lord is
2. Re - joice! Re-joice when Je - sus
3. No more will sin and sor - row
4. Re - joice! Re-joice in the Most
1. Joy to the world! The
f
F.
705
706
707
708
709
710
711
712
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718

Chapter Six

MDT Test Generation and Question Styles

6.1 Introduction

Whether from academic training or practical classroom experience, teachers acquire a wide range of test making skills with varying degrees of quality. The MDT innovation can improve question quality by giving teachers new alternatives for machine scored question formats. However, the instructor (not the method) is still the deciding factor about question content. This chapter neither attempts to discuss the background to testing strategies nor to "teach the teachers." The objective is simply to highlight the capabilities (and the few limitations) of MDT multi-digit questions.

6.2 Number Of Questions And Range Of Scores

Tests with MDT multi-digit answer bank questions should have fewer questions than traditional multiple choice, matching and true/false formats for two reasons. First, it takes students longer to arrive at their answers and encode them properly onto the answer sheets. Second, because of increased academic rigor, the point spreads of students' scores are more evident when MDT recall-style questions are asked than when five-choice questions are used.

Concerning the first issue, and depending on the difficulty levels of questions and ability levels of students, the desirable number of questions on a typical fifty minute test is between forty and seventy-five. A few multiple choice questions can always be included where appropriate. No one has yet experimented with the impact of the MDT innovation in testing situations where time and speed are critical factors. Before attempting such a test, it is advisable the instructor has clearly in mind the purpose and objectives of such an experiment.

The greater point spread of student scores overcomes two problems of objective tests. The outright guess factor of twenty percent for five-choice questions and fifty percent for True/False is reduced to less than one percent. Furthermore, mere recognition out of five offered responses and the process of elimination are greatly reduced. The result is that a multi-digit test is much harder for unprepared students but is only slightly harder for well prepared ones. Student comments reflect this; student scores show it. As an estimate, consider a traditional test which produces scores from ninety-five to fifty-five with a mean in the upper seventies. An MDT long-list test on similar content is expected to have scores from eighty-five to twenty-five with a mean in the upper fifties. Further comments are made in Section 7.4.

6.3 Limitations On The Use Of MDT Questions

6.3.1 When Elimination of Alternatives is Important: The MDT multi-digit method is generally not applicable when the student is expected to use thought processes to eliminate some or all of the alternative answers. In these cases, the five-choice method can be quite appropriate. In the context of matching, the use of up to ten alternatives could also be applicable. An MDT method of response could be used when the list is still relatively short, with up to twenty alternatives in viable groupings. An example is the case of the major climatic types, (twelve to sixteen, depending on the classification used) frequently taught in geography courses; the student is supposed to be able to distinguish among the alternatives.

6.3.2 With Questions such as **"Which of the following is not . . ."**: Because the multi-digit method can contain hundreds or even thousands of alternatives, there are many alternatives in the list that could not possibly be an appropriate response for a given question. This "which of the following is not . . ." type of question is not used in multi-digit tests style nor in fill-in-the-blank exams. It makes no sense to ask: "Mr. __(blank)__ was not a President of the United States."

6.4 Additional Ways And Means Of Using MDT Responses

6.4.1 For True and False Questions: The MDT format can be used with a standard True-False question merely by offering only the two responses, told to the students along with the questions (that is, not in a long list). An appropriate selection could be 001 equals True and 002 equals False. Of course, any other pair of numbers could be used as long as the student is told. The words True and False could be given at the very end of a long list, in which case they could be numbers 997 and 998. Alternatively, the words "True" and "False" could be included in their alphabetical positions on the list. However, this requires the student to do unnecessary searching for code numbers, since the question is written so only two options are open. Therefore, the best option is to have the appropriate codes for these two responses offered in the question or in the instructions for the exam.

6.4.2 For Multiple Choice Questions: In the case of traditional multiple choice questions, which usually have five alternative answers, the responses provided by the professor could be specifically encoded as 001, 002, . . . 005. (Note: On most of the MDT computer scoring software packages there is no need to encode the leading zeros, those to the left of the important digits.) A further modification would be to have the five choices for each question encoded with their own distinctive code numbers. This can be an advantage because the computer can retain word messages in conjunction with each response code, it is possible to obtain distinctive feedback from each response. For example, question 15 could have five alternative responses which are numbered 430, 431, . . . 434. This is a "mini-list", not part of an alphabetized long list. The computer-generated feedback could indicate that the response 433 was correct and print out the appropriate word or phrase answer. Diagnostic messages for each of the four incorrect responses could also be generated, however, care should be taken so the code number does not somehow reveal which answer is the correct one and which are the incorrect ones. For example, do not give distinctive numbers (like multiples of five) to the correct answers. The code numbers for the five alternatives need not be in consecutive order because the five choices with their code numbers will be typed out on the test sheet as well as on the diskette file of the long list which is accessed by the computer. In other words, terms selected from the computer-accessed long list could retain their actual code numbers even when used in a five-choice question.

6.4.3 For Definition Type Questions: A typical opening phrase for a definition question could be: "Match the following definition or statement with the proper term on the attached long list." A series of questions could then follow, being written only in the form of phrased definitions. A glossary at the end of a textbook could be used for the definitions, but instructors could make wording modifications to encourage learning beyond rote response.

6.4.4 For Numeric Responses: With the MDT method, actual calculated numbers can be their own answer codes. In this case, no list is needed. Section 5.7 and Figure 5-2 explain some of the methods. Alternatively, the student may be asked to select the answer from those offered by the instructor either with each specific question or in a "mini-list" to which they are directed in the questions. For example: "Using the List BB of numerical values at the bottom of this page, indicate how many millions of people live in the United States of America as of the mid-1980's. Select the best answer." **Each number is its own code** to be marked on the answer sheet. The BB list of numbers could be: 176; 193; 215; 227; 238; 249; 260; 271 (additional numbers could be added by an instructor who might use this same list for answers to another question). (Note: The correct answer is 238 million people.)

The units of measurement and the position of a decimal point must be specified in the question. Alternatively, standard scientific notation could be appropriate for some science courses. Robert Freeman at Oklahoma State University is working with this technique in his chemistry course. An answer such as 3.82×10^{-12} would be encoded in two three-digit responses: 382 and 912, where the student is instructed that a negative exponent is indicated by a 9 in the hundreds position of the exponent response. Therefore, the range of answers is from 1.00 to 9.99 with exponents from 899 down past 1 to negative 99. The potential of the MDT innovation is very evident and applicable to any situation with a numerical response. Comment:

Because of the increasing number of cells a student needs to darken for each question, it is imperative the student exercise more care with this testing method.

6.4.5 For Several Short but Distinctive Lists: Sometimes a short list of alternatives could be used repeatedly for different questions. It is possible to print the list as an identifiable subgroup of the long list to which the student can refer when needed. This is especially appropriate when there is a finite list of terms the teacher would like to have listed and encoded together. For example, to have all the climate types printed and numbered together, simply make each List Maker entry start with the word Climate, as in "Climate--Humid Continental" and "Climate--Mediterranean". This technique could also be used with short lists such as semantic differentials where there are seven choices ranging from a strongly unfavorable to strongly favorable opinion. Many questions could refer to the list, thus the questions need only direct the student to "Select the desired alternative from the special list for Climate" or "Use Climate List".

When two or more sub-lists are printed on separate sheets or front and back sides of paper, it is sometimes confusing for students to know which list to use. It is also disconcerting to students to be continuously flipping from one list to another. To eliminate this problem, it is advisable to group questions together according to the list to which they pertain. At the beginning of a group of questions or with each question, the name of the associated list(s) should be clearly identified.

6.5 The Use Of Supplementary Pages

When using supplementary pages (see Section 5.11) such as maps or diagrams in a test, it is desirable to have all relevant questions clustered together. This saves the student from flipping pages back and forth. In writing the specific questions, to mention at the beginning of the question or at the beginning of the cluster of questions that the student should refer to a particular supplementary page.

Examples using Figures in this book:

Weak: What is the name of the organ shown by number 61 on Figure 5-6?

Better: On Figure 5-6, name the organ indicated by number 66.

Best: Questions 6, 7 and 8 refer to Figure 5-6c (bones).

6. Bone indicated by number 322.
7. Bone at number 316.
8. Identification number of the clavicle.

To assist students and avoid confusion as to what is expected, it is helpful to underline the specific feature being requested. This is especially important when there are several different items, places or features needed in the specification of a question. For example:

1. On map 2, name the major river which runs between state number 6 and the province to the east of it.
2. On Map 11 there is a country to the east of location 24. Name the city which was the capital, not the present day capital city, during the 1800s.

It is equally appropriate to ask questions for which the answer would be a number taken from one of the supplemental sheets and not the long list. For example:

3. On Figure 5-6c, what is the identification number which indicates the left femur bone?

In order to easily generate different versions of virtually the same test, it is possible to simply change one of the supplemental pages. For example, two diagrams with differently numbered locations could be the basis for having two different versions. Making the different diagrams is as simple as renumbering one copy from top to bottom when the other version is numbered from bottom to top. Be sure the two versions have a distinctive mark in one corner, or print them on different colored paper. In all other respects, the diagrams could be exactly the same.

6.6 Generating Foils For Multiple Choice Exams

In an effort to find plausible (yet still incorrect) alternative responses for traditional multiple choice tests, instructors have experimented with using fill-in-the-blank tests to see what answers a typical group of students would give. This is a time consuming method. The MDT multi-digit testing method could be used in a similar way to determine the best possible foils. But this raises a question: Since the MDT method is already a computer-scored technique, why not use it where appropriate instead of trying to merely create a list of five alternatives?

6.7 Making Banks Of Questions

With the previously mentioned hardware, software, answer forms and lists available, it is possible to make and administer an MDT test. The actual selection of questions is usually an individual matter for each instructor. The features of the MDT System greatly facilitate the generation of questions. Most specifically, because there is no need to think up the four incorrect alternative answers, making MDT multi-digit style questions is about as easy as making fill-in-the-blank questions. Only the stem of the question is written. Likewise, entire "families" of questions can be formulated with a simple statement such as "name the feature designated by arrow number (26) on diagram (14)." By merely changing the numbers, the same question is utilized repeatedly, even within the same test. See Sections 5.11 and 6.5 about the use of diagrams.

It is envisioned that textbook publishers will someday soon make significant contributions to question banks using the MDT method. Publishers already contribute multiple choice item banks; that information is available to teachers as part of publishers' services to promote sales. The banks are much easier to do now that there is a functional distinction between answer banks (long lists), question banks (just stems) and traditional item banks for multiple choice items. Note: If question banks or question families were available to students (either openly or surreptitiously obtained), there would be almost no impact on the validity of the testing. Tests using MDT style answer banks and question banks can easily be modified to create new versions.

Many instructors have long dreamed of having a question bank or card file of questions from which to quickly and easily select appropriate and valid questions. Some have accomplished this feat; others rely upon their previous tests or upon some questions provided by textbook publishers. The MDT Educational System facilitates the making of a question bank because long lists are essentially "answer banks". Each of the terms on the list could be used as the answer for a variety of questions. Since four wrong alternatives do not need to be specified, the creation of a new question is as easy as looking at the long list answer bank and then phrasing the question. As has been mentioned earlier in this chapter, it is also possible to create some generic forms of questions when they relate to supplementary pages, to definitions or to topics for which there could be many questions asked. An example of this is: What chemical (molecule, element, amino acid, compound, etc., as selected by the instructor) is identified by the symbol Ca, H_2O, etc.?

With the availability of microcomputers and word processors, an MDT test generating package would be a natural addition to the system. Based on the code number of the selected answer about which the instructor wishes to ask a question, the computer could easily display on the screen a selection of questions that would have the designated answer. The instructor would then merely indicate which of the questions he/she desired for automatic insertion into the test. Likewise, the question selection could be left to the computer after the instructor specifies the topic, difficulty and other factors. The use of a microcomputer in test preparation could also result in the printout of an answer key and the selection of different but equivalent questions which could be used in other versions of the same test with different classes or in different semesters. Multi-Digit Technologies Corporation intends to offer a test-making package that incorporates the various MDT special features as sufficient demand is demonstrated.

6.8 Subdivisions Or Part Scores

The various MDT computer programs for test scoring permit the grouping of questions into parts (subtotals) with different point values for questions in each part. Separate subtotals for instructor-designated parts of tests are provided in various feedback forms. (See Section 7.5.1 and Figures 7-1, 7-5 and 7-6.) Subtotals are useful tools to help evaluate student progress. The number of parts varies with the answer form and software version. Up to twelve parts can be specified on MDT4, the mainframe computer program which best illustrates this feature of variable point values. On the F1 and D1 answer sheets, up to six parts can be obtained of the fifty MDT answer bank questions and an additional six parts from the seventy-five multiple choice questions. The questions must be contiguous, that is, grouped together, to be in the same part. Within each of these twelve parts, a different point value can be determined. Any point value from zero to nine hundred ninety-nine points per question can be designated, however, it is undesirable to have point values in excess of ten points per question unless there are extenuating circumstances. Except in the extreme case in which the combined questions in a part are worth more than nine hundred ninety-nine points, the three-digit spaces for point scores on the printout should be adequate.

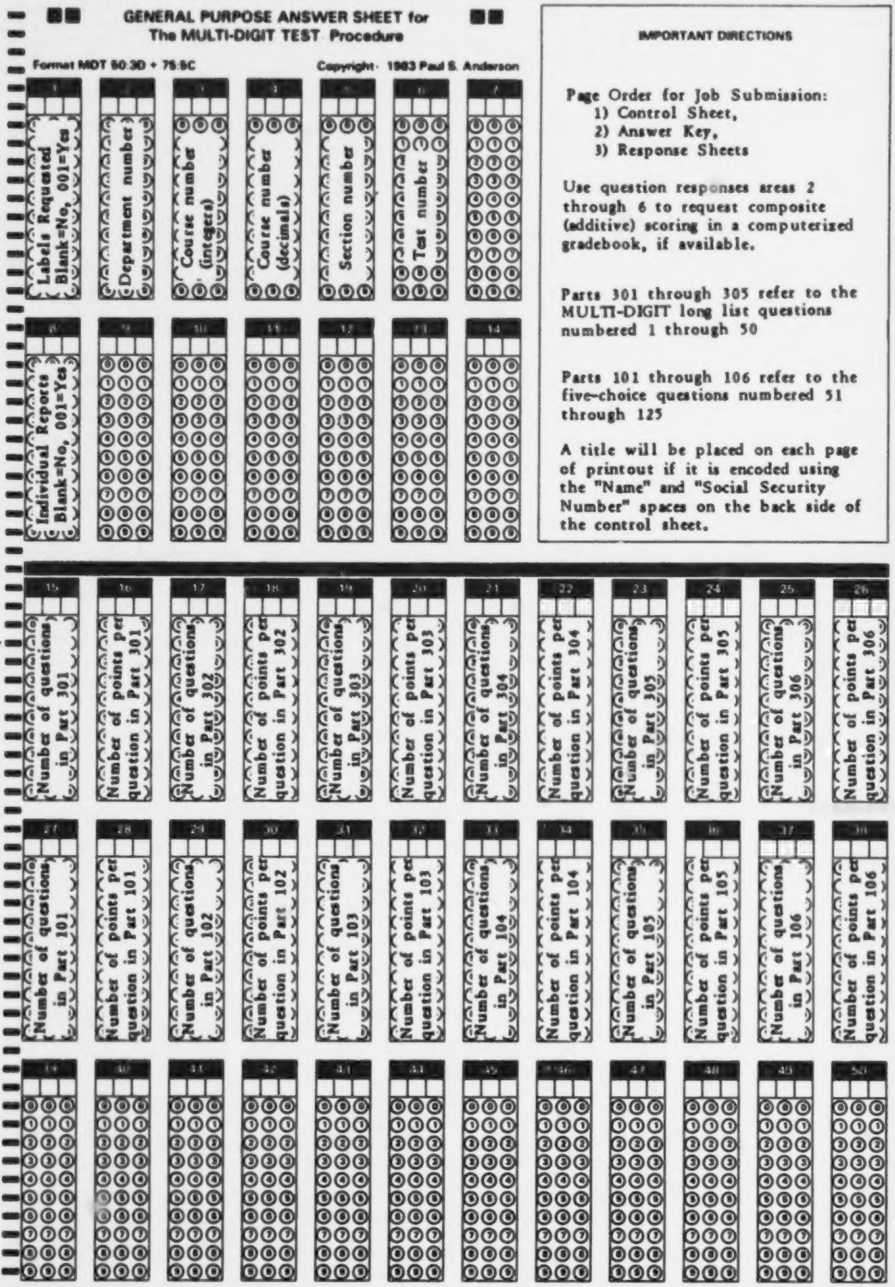
The point values are marked on the control sheet which is read with the answer key when the student sheets are scanned. The format for marking these point values is shown in Figure 6-1. The six parts from the multi-digit portion are marked in the positions for questions 15-26 on form F1 or D1. Each of those parts is called 301-306, the "three" indicating it is part of the three-digit portion of the answer sheet. Two question grids are used to define each part. For example the space for question 15 would include the number of questions in part 301. In question 16 the points per question in part 301 would be identified. Part 302 utilizes question grids for numbers 17 and 18, etc. Totalling the number of questions identified on spaces 15, 17, 19, 21, 23 and 25 should equal the total number of questions on the three-digit side of the answer sheet. To determine the total points in the first fifty questions, multiply the number of questions times the number of points per question in each part, then add them together. The five-choice parts (101-106) are identified in a similar way using the spaces for questions 27-38 on the control sheet. Note: The control sheet is physically no different from the student answer sheets. While this might lead to minor confusion in the initial times of usage, it results in cost savings because the instructors or schools do not need to purchase an additional and differently formatted scannable sheet. Some advantages of the part scores (subtotals) are mentioned in Section 7.5.6.

6.9 Noncontiguous Parts With Variable Scores

One of the forthcoming additions to the MDT mainframe software will allow the instructor to specify noncontiguous parts. In this feature, the instructor specifies into which part a question is placed, regardless of the question number anywhere on the answer form. Furthermore, each

Figure 6-1 Model for MDT Control Sheet (Mainframe only)

MODEL FOR THE CONTROL SHEET FOR TEST SCORING WITH PROGRAM MDT4



GENERAL PURPOSE ANSWER SHEET for
The MULTI-DIGIT TEST Procedure

Format MDT 50:30 + 75:5C

Copyright · 1983 Paul S. Anderson

IMPORTANT DIRECTIONS

Page Order for Job Submission:
1) Control Sheet,
2) Answer Key,
3) Response Sheets

Use question responses areas 2 through 6 to request composite (additive) scoring in a computerized gradebook, if available.

Parts 301 through 305 refer to the MULTI-DIGIT long list questions numbered 1 through 50

Parts 101 through 106 refer to the five-choice questions numbered 51 through 125

A title will be placed on each page of printout if it is encoded using the "Name" and "Social Security Number" spaces on the back side of the control sheet.

1 Labels Requested Blank=No, 001=Yes
2 Department number
3 Course number (integers)
4 Course number (decimals)
5 Section number
6 Test number
7
8 Individual Reports Blank=No, 001=Yes
9
10
11
12
13
14
15 Number of questions in Part 301
16 Number of points per question in Part 301
17 Number of questions in Part 302
18 Number of points per question in Part 302
19 Number of questions in Part 303
20 Number of points per question in Part 303
21 Number of questions in Part 304
22 Number of points per question in Part 304
23 Number of questions in Part 305
24 Number of points per question in Part 305
25 Number of questions in Part 306
26 Number of points per question in Part 306
27 Number of questions in Part 101
28 Number of points per question in Part 101
29 Number of questions in Part 102
30 Number of points per question in Part 102
31 Number of questions in Part 103
32 Number of points per question in Part 103
33 Number of questions in Part 104
34 Number of points per question in Part 104
35 Number of questions in Part 105
36 Number of points per question in Part 105
37 Number of questions in Part 106
38 Number of points per question in Part 106
39
40
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question can have any point value from zero to nine hundred ninety-nine. Default values (if nothing is specified) give one point per question and tally the scores into a single part. Specific instructions for this will be provided once the MDT5 program is released.

As with all testing, it remains the responsibility of the instructor to specify and control the total number of points on any given test. Because additional features are available with MDT answer sheets and computer software, it is advisable more attention be paid by each instructor when setting point values.

6.10 Conclusion

Many other comments relevant to test generation are found in later chapters in which educational issues, including higher orders of learning, are discussed. Furthermore, in those chapters there are discussions of how the MDT innovation can relate in specific ways to distinct academic disciplines with special needs.

The discussion has been entirely about the MDT multi-digit innovation. However, the MDT short answer (SA) feature (see Section 7.6) opens further flexibility for instructors. When used to its full capabilities, the MDT Educational System brings major increases in computer assistance to all styles of educational measurement ranging from true-false to fill-in-the-blank to essay questions.

The ultimate objective of these and all other testing methods relate specifically to the learning behavior of the students and the relevant feedback. Chapter Seven contains considerable information of interest to the instructor at the time of making the test, as well as to the students when they prepare for and take MDT examinations.

Chapter Seven

In the Classroom

7.1 Introducing MDT Multi-Digit Testing To Your Students

The administration of an MDT multi-digit test in the classroom can be facilitated by properly introducing the students to the MDT method and anticipating their reactions. This chapter provides that information and also deals with the computer-generated feedback that aids students in their learning and assists instructors with better analyses in less time.

You should inform your students as early as possible, preferably on the course syllabus or first week of class, that their examinations will include questions in the MDT format. This is particularly important if your students are otherwise expecting traditional multiple choice questions. If your students normally expect fill-in-the-blank exams, there is a minimum of difference with regard to how they choose to study. The best and simplest explanation is to tell the students that **a machine-scored approximation of a fill-in-the-blank exam will be used for some portions of the examinations.** It is also useful to show them at an early date examples of the answer sheet and a long list. For large classes this is easily done with transparencies on an overhead projector or by passing around the actual sheets of paper. For educational purposes, instructors should feel at liberty to make transparencies of any figures in this book to explain the MDT method to their students. Within a few years the MDT innovation should be sufficiently known on campuses that explanations will no longer be needed. However, in the initial semesters of operation, it is desirable to inform your students and to familiarize them with the basic components of the MDT system.

To facilitate the functioning of the MDT method and to prevent misunderstandings by students, it is important to inform them of a series of rules and suggestions concerning MDT answer bank questions. These rules have been summarized below in Section 7.2 so they may be easily photocopied and circulated to students.

7.2 Basic MDT Rules For All Students (And Their Instructors)

1. **Familiarize yourself with the basic MDT format** of answer sheets and long lists; read the printed instructions on the answer sheets.
2. There are **small boxes at the top of each answer grid** in which you can write your numerical numbers above the appropriate columns of marking cells (circles, ovals or rectangles). To write the numbers in these boxes is optional, but advisable.
3. **The actual scored answer is read from the blackened cells**, with one cell in each column for each digit. It is the student's responsibility to correctly mark the answer sheet. It is unreasonable to expect points to be awarded if the correct number is written in the row of boxes above each answer block but is improperly coded in the cells. What the instructor receives in his printout relates specifically to what the scanner has observed and has no relevance to the numerical response in the small boxes.
4. As with all machine scored tests, **use only black lead #2 pencils**; make all marks very dark and completely fill the selected cells. Cleanly erase any answer you wish to change and make no stray marks on either side of the answer sheet.
5. Unless stated differently by the examination supervisor, **zeros and blanks are read the same by the computer program.** Therefore, any blank column is a zero digit. In the case of a changed answer from a digit 1-9 to a zero, the zero must definitely be marked. Otherwise an erased but faintly visible mark for the other digit could be read by the computer as being the desired mark. It is advisable that students always fill in any zeros in each answer.
6. Unless indicated differently by your instructor or on the long list provided for your test, **the code number 999** means "No reasonable answer is on the list(s)" used for this test.

7. **Modifier words are not provided on the long lists.** Therefore, a name such as Huron could refer to the Indian tribe, Lake Huron, Huron County or Huron brand fishing poles. The context of the question will indicate how the word is being used. It is, therefore, not a valid argument for students to say they were unable to answer a question concerning that body of water because the word "lake" was not used with Huron.
8. The words on the long list are not intended to conform with normal rules concerning **plurals, adjectives and adverbial forms**, unless the instructor prepares lists with those capabilities. For example, the response Democrat could also be read to mean Democrats or Democratic.
9. When a response has two or more words in it and the student does not find the response in the long list as he/she first thinks it should be, he/she should automatically **check the list for the reversal of the key words.** For example: the "Bill of Rights" could be listed in two ways: a) Bill of Rights or b) Rights, Bill of. They would be in different alphabetical positions on the long list, but only one will be given (or both would have the same code number). In keeping with the previous example, the body of water Lake Huron could be indicated as simply a) Huron, b) Huron, Lake or c) Lake Huron. Likewise, the Great Salt Lake could be listed as a) Lake, Great Salt, b) Great Salt without the word lake, or less likely as c) Salt, Great. The actual structure of the list is at the discretion of the individual instructor, but is not intended to be tricky. Teachers are encouraged to avoid ambiguous or inconsistent usage of modifier words or word order. However, it should be clear to both instructors and students that if a question asks about a specific lake, it would defeat the multi-digit test objectives if the only responses possible were 5-15 different names all beginning with the word "Lake".
10. **Be sure that you are looking at and using the correct list or lists.** Generally the instructor will specify which list(s) should be used for the different questions. Unless so indicated, the students are to assume ALL of the lists distributed for the test should be used. To avoid confusing or intermixing different versions of list pages which are not exactly identical,

each printed copy of a list has a distinctive name, special mark, distinctive design or code. For example, an "AA" in the upper right hand corner of the front side of a long list clearly separates it from the sheets marked "BB" for a different version.

11. In the case of accidentally having **two identical or essentially synonymous word responses on a list** or on two lists in use, the students should encode the lowest number (this means the lowest number in counting order, not the lowest number in position on the page). Instructors should endeavor to avoid these situations as much as possible, but errors can occur. The reason for indicating the use of the lowest number is to have the maximum number of people responding with the same code number. This will minimize the instructor's task to correct the problem by giving points earned to students who did happen to use the other number. Whenever this occurs it will be obvious in the MDT computer-generated printout because the words are written alongside the numbers in the item analysis and on the student feedback sheets. The printout will clearly illustrate an appropriate word response did not receive credit as an acceptable answer. In these cases, the students have a legitimate reason to expect an increase in their points earned on the test.
12. For MDT multi-digit questions, there is **not much sense in guessing** if a student really does not know the answer. With the chances generally being one out of nine hundred ninety-nine, the likelihood of guessing correctly is minimal. Furthermore, the time wasted trying to search and guess from the long list could be better spent with other questions on the test.
13. The lists are long because it is intended that students should not be able to read through the entire long list(s). A student comment such as "I didn't have time to read through the whole list" is an unsatisfactory reason for requesting additional time to take the test. **Be prepared; you are expected to know the answers.**

7.3 Classroom Situations

7.3.1 Seating and Writing Space: The ideal classroom arrangement for administrating an MDT multi-digit test has plenty of table space for each student to spread their materials and write their answers. Note that the number of pieces of paper on any given test is increased by at least one, being the long list. The use of any supplemental sheets such as maps or diagrams further increases the number of pages to be managed. The control of these different sheets is a point of difficulty for some students and it will assist these students if they have sufficient space on which to lay their pages.

In classrooms with only armrest space on which to write answers, students are recommended to place the answer sheet on the armrest, hold the question sheet in their non-writing hand and have the long list on their lap. Many students choose to slide the long list under their answer sheet on the armrest of their seat. The space limitations emphasize the importance of having any list(s) for a given test on a single piece of paper, although it could be on the front and back sides. It might be comforting to mention to your students that multi-digit tests with these various pieces of paper have been used since 1983, including cases of solidly packed rooms with over three hundred fifty students, each having only a single armrest on which to write. Testing under these circumstances certainly can be done. The lack of ideal physical facilities is not reason to compromise the teachers' educational objectives and choice of examination tools.

7.3.2 Passing Out Materials: It is not desirable to staple all of the testing components together. The answer sheets should never be stapled because they will be machine scored later. The long lists should also be separate so the student can easily refer to the front and back sides throughout the test. If everything needs to be packaged together for ease of distribution, a paper clip or an envelope for each set of materials is probably the solution. However, what is commonly done is to simply pass out the various sheets of paper either as the students enter the room or after they are seated. Because of the need to encode names and identification numbers, pass the answer sheets out first. The pages with the test questions are usually the last items to be distributed.

7.3.3 Stray Marks and Darkest Marks Discrimination: National Computer Systems (NCS) optical scanners read through the paper of the answer sheet. Therefore, stray marks, even those anywhere on the back side of the form, could invalidate an answer which is marked on the opposite side of the page. Having no stray marks is of even greater importance with the MDT answer sheets because of the high percentage of all possible cells used. The scanners from Cognitronics are reflective readers, so marks on the back of an answer sheet are unimportant. However, they must not cause darkness on the scanned side. For example, ink can penetrate through paper or dirt from a table and ink from an underlying sheet can adhere to the down side as the student writes hard on the opposite side.

For every question there are alternative cells for each answer. True/False have two; multiple choice have five; the MDT long-list questions have ten (in each of the three columns); and the name grid letters have twenty-six or twenty-seven. Every cell is sensed and then the darkness reading is compared electronically. For card readers and other low cost scanners, the comparison is only against a pre-set level of sensitivity. WATCH OUT! Erasure marks, unless completely eliminated, can sometimes be sensed. If two or more marks in a grid are detected on the low cost scanners, the machine sends an "invalid mark" message. The result is an incorrect answer and zero points.

At present only two brands of scanners readily available in the United States overcome this problem. Both the Cognitronics and the National Computer Systems (NCS) sheet scanners have a darkest mark discrimination capability. In this, the sensed marks in a grid are compared against multiple pre-set levels of sensitivity and then against each other. The erasure marks can be clearly differentiated from intended marks. Only when an answer grid has two equally dark marks is it declared invalid. Otherwise, the machine can correctly select the darkest mark.

During the first three years many MDT tests were manually regraded to see if the marked cells corresponded with the handwritten number in the box above each column for the three-digit answers. The regrading highlighted how some students must be punishing themselves by incorrectly darkening the cells. In general, if the printed number inside the cell can be easily read after it has been marked, the mark is too light. The mark discrimination capabilities of Cognitronics and NCS scanners are excellent, but very light marking by a student can push the capabilities to their limits. In such cases, it is clearly the student who is responsible for any lost points.

7.4 Scoring MDT Tests

At the conclusion of the test period, the instructor submits the answer forms to the test scoring office (or gathers them to be graded with a microcomputer MDT system). It is not necessary to place the student answer sheets in any special order because the computer does any needed alphabetizing. The instructor must remember to place the answer key immediately on top of the pile of student answers. Above the key is the control sheet (or sheets in some cases). The completed scoring and printed analyses should be available from one hour to forty-eight hours later depending on the facilities at your school.

The general opinion of students who have taken MDT tests has been that the test eliminated much of their success in guessing. Certainly students who have developed the techniques of selecting correct answers from a list of five, in part by chance or intuition, will find that this method severely limits their "luck". This realization leads students to expect their average scores to be lower with this test system than with similar questions on a five-choice exam. The solution for this problem is simply to assure the students that a set criterion, such as "ninety percent and above being an A," has not been predetermined, especially while the MDT testing method is under initial evaluation. The use of grading on a curve and the professor's experienced opinion as to what would constitute an A, B or C grade are usually sufficient assurances to allay the fears of the vast majority of students concerned about their grades because of the increased test rigor.

Most of the initial users of MDT testing have implemented a curve in their grading systems. The use or nonuse of a curve is at the discretion of the individual instructor and should be seen as neither a detriment nor an advantage to the MDT system. If an instructor desires to have increased rigor without modifying the grading scale, that is an appropriate decision in certain courses. It is a known fact that an experienced teacher can formulate tests for the same group of students in which one test is so easy that virtually everyone scores above ninety percent, while another test is so difficult the same students average in the thirties. In other words, the instructor still remains in complete control of the testing situation. The MDT method is an additional tool, but it in no way dictates the academic levels required by each instructor. On the other hand, the

MDT innovation does permit an instructor to obtain greater academic rigor and still retain the advantages of scanner-assisted scoring.

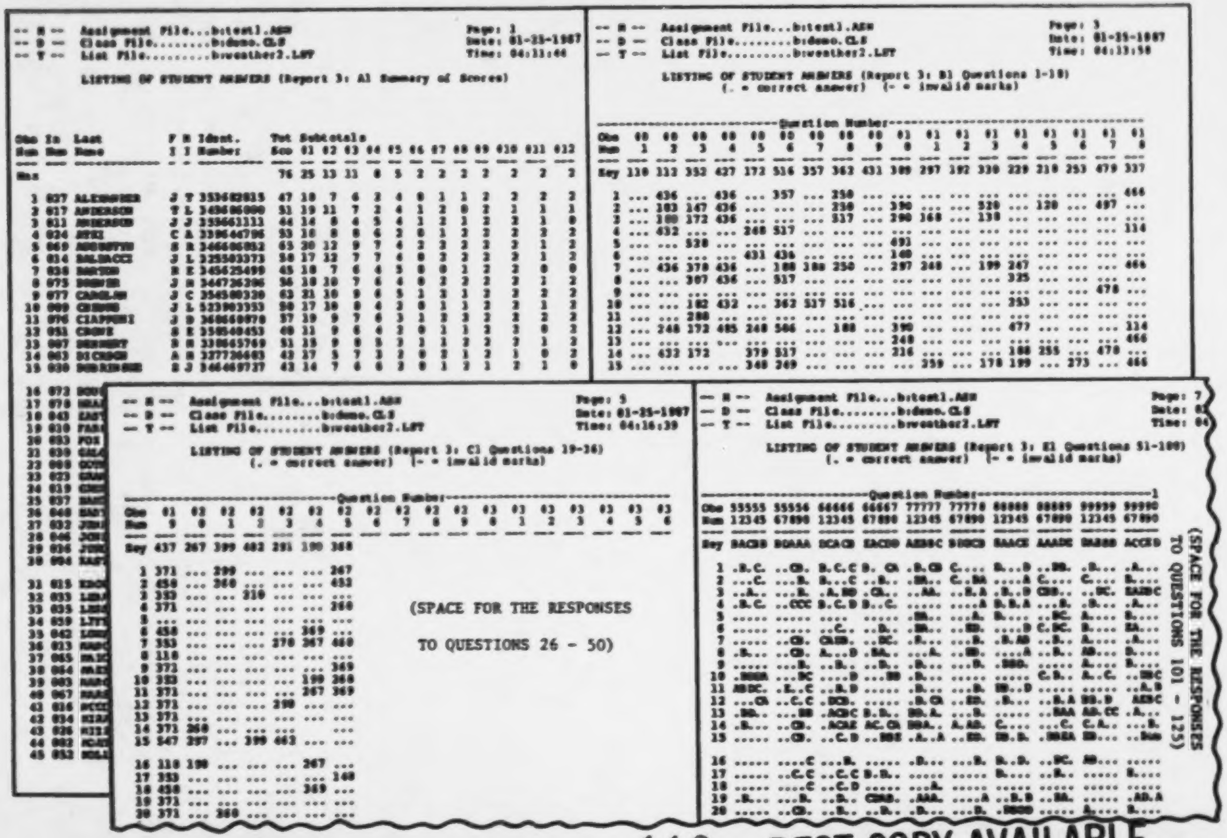
7.5 Results Generated By The Computer

With a few commands, reams of computer output can be generated to assist the educational process. An underlying advantage of the MDT Educational System over previous methods is that the computer has access to all of the words which correspond to each separate code number. Not only can the teacher and students be told which code numbers were answered, but the correct and incorrect word responses can also be printed. In this section the various parts of the computer-generated feedback are discussed.

7.5.1 The Full Listing or "Dump": The full listing is often called a "dump" because it places onto paper all of the information that the computer has extracted from each student's answer form. See the example in Figure 7-1. The first number is the student's line number because it takes two or three lines to show all the information in the full listing. The observation number is second and specifies the place of the answer sheet in the pile of forms as read by the computer. This can be useful in case you need to find a particular answer form. The last name and then the first name and/or initials are provided. In the case of the MDT systems which use NCS or Cognitronics scanners, the names are exactly as read from the sheets. For the version from cards, the names are derived from a computer file using the student's ID or identification number. Whatever the source of names, the report is presented in alphabetical order. If the student failed to fill in the name area or there is no match between a name and an identification number on the cards version, no name is available and the computer places the student's data at the very beginning before the A's. Because this causes a minor inconvenience, instructors should emphasize that all students should accurately encode their names and identification numbers on the answer forms.

Total score is next, followed by the scores for the various parts (subtotals) as defined by the instructor on the control sheets. Except in special circumstances available with modified software, the total represents the sum of all the specified part scores. The scores for the short answer (SA) essay questions (if available on the answer form) are

Figure 7-1 Printout of All Student Responses ("Dump")



```
-- N --   Assignment File...b:test1.ASW                Page: 1
-- D --   Class File.........b:demo.CLS                Date: 01-25-1987
-- T --   List File..........b:weather2.LST            Time: 04:11:44

          LISTING OF STUDENT ANSWERS (Report 3: A1 Summary of Scores)
```

```
-- N --   Assignment File...b:test1.ASW                Page: 3
-- D --   Class File.........b:demo.CLS                Date: 01-25-1987
-- T --   List File..........b:weather2.LST            Time: 04:13:58

          LISTING OF STUDENT ANSWERS (Report 3: B1 Questions 1-18)
                 (. = correct answer)  (- = invalid marks)
```

```
-- N --   Assignment File...b:test1.ASW                Page: 5
-- D --   Class File.........b:demo.CLS                Date: 01-25-1987
-- T --   List File..........b:weather2.LST            Time: 04:16:39

          LISTING OF STUDENT ANSWERS (Report 3: C1 Questions 19-36)
                 (. = correct answer)  (- = invalid marks)
```

(SPACE FOR THE RESPONSES

TO QUESTIONS 26 - 50)

```
-- N --   Assignment File...b:test1.ASW                Page: 7
-- D --   Class File.........b:demo.CLS                Date: 0
-- T --   List File..........b:weather2.LST            Time: 04

          LISTING OF STUDENT ANSWERS (Report 3: E1 Questions 51-100)
                 (. = correct answer)  (- = invalid marks)
```

(SPACE FOR THE RESPONSES TO QUESTIONS 101 - 125)

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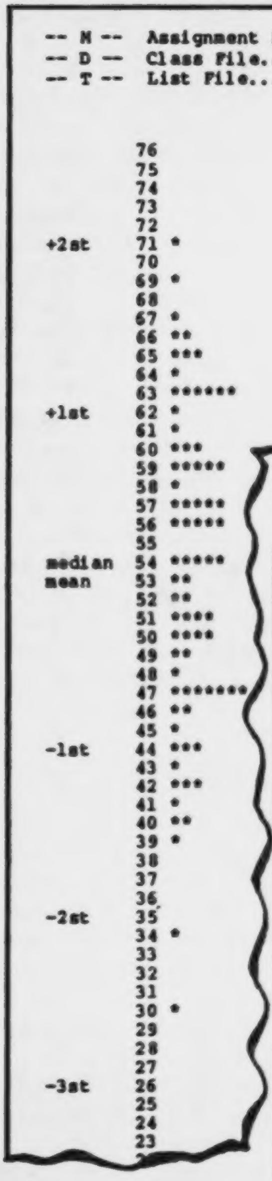
also given. (The MDT SA features are discussed in Section 7.7.) The remainder and vast majority of the full listing indicates each student's response for each question. The correct answer for each question is given in the header of each section of the dump. If the student answered the question correctly and earned points for it, a dot is printed in the corresponding position. In this way, the answers which were incorrect are highlighted and easily identified. If the instructor wants to identify students who gave a particular incorrect answer, simply place a ruler or the edge of a sheet of paper vertically next to the question which is being reconsidered. It is then easy to identify all cases where individuals gave specific responses to those questions. (See also the discussion of the item analysis data in Section 7.5.3.)

7.5.2 Histograms and Statistical Values: For each of the designated parts of the test and for the total score, a histogram (frequency distribution of scores) is printed along with the statistical values of mean, median, standard deviation and several other items as illustrated in Figure 7-2. (Please note: The microcomputer version only gives a histogram for the total, not parts, because of time and paper constraints.) These histograms and statistics can be especially useful when deciding on the distribution of grades and for identifying students who are doing exceptionally well or poorly.

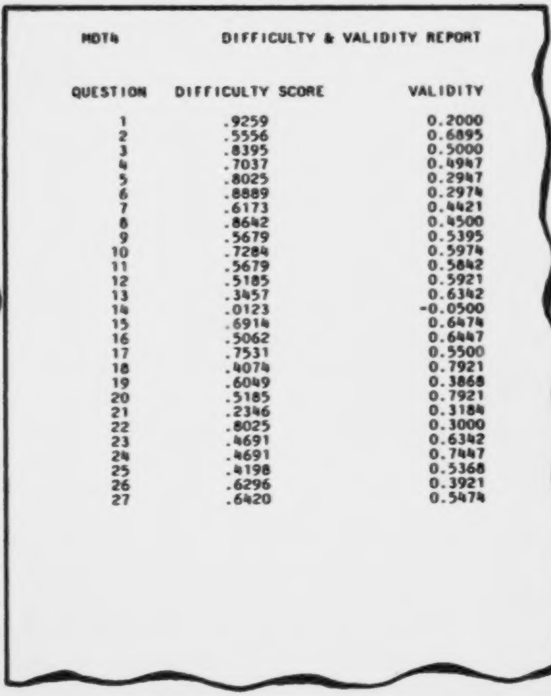
7.5.3 Difficulty and Discrimination Indices: For each question the difficulty level and discrimination index are calculated (Figure 7-3). Difficulty is calculated as the proportion of students who have correctly answered the question. If everyone answered it correctly, the difficulty level would be 1.00. If sixty percent were correct, the difficulty would be 0.60, etc. Questions that all students get correct or all students miss are not generally considered to be good. In general, difficulty levels from 0.4 to 0.7 are considered most desirable. However, there are some instances where teachers might want to ask questions that are very easy or very hard in order to identify weak students or those who are well prepared. Once again, this is a matter of individual preference and not something dictated by the MDT testing method. Separate academic research concerning difficulty levels can be consulted.

Figure 7-2 Histogram of Student Scores from MDT (Microcomputer)



```
-- M --  Assignment File...b:test1.ASN                          Page
-- D --  Class File........b:demo.CLS                           Dat
-- T --  List File.........b:weather2.LST                       Tim

                       HISTOGRAM OF TOTAL SCORES (Report 7)

         76
         75
         74
         73
         72
+2st     71 *
         70
         69 *
         68
         67 *
         66 **
         65 ***
         64 *
         63 ******
+1st     62 *
         61 *
         60 ***
         59 *****
         58 *
         57 *****
         56 *****
         55
median   54 *****
mean     53 **
         52 **
         51 ****
         50 ****
         49 **
         48 *
         47 *******
         46 **
         45 *
-1st     44 ***
         43 *
         42 ***
         41 *
         40 **
         39 *
         38
         37
         36
-2st     35
         34 *
         33
         32
         31
         30 *
         29
         28
         27
-3st     26
         25
         24
         23
```

Figure 7-3 Difficulty and Validity Report from MDT4



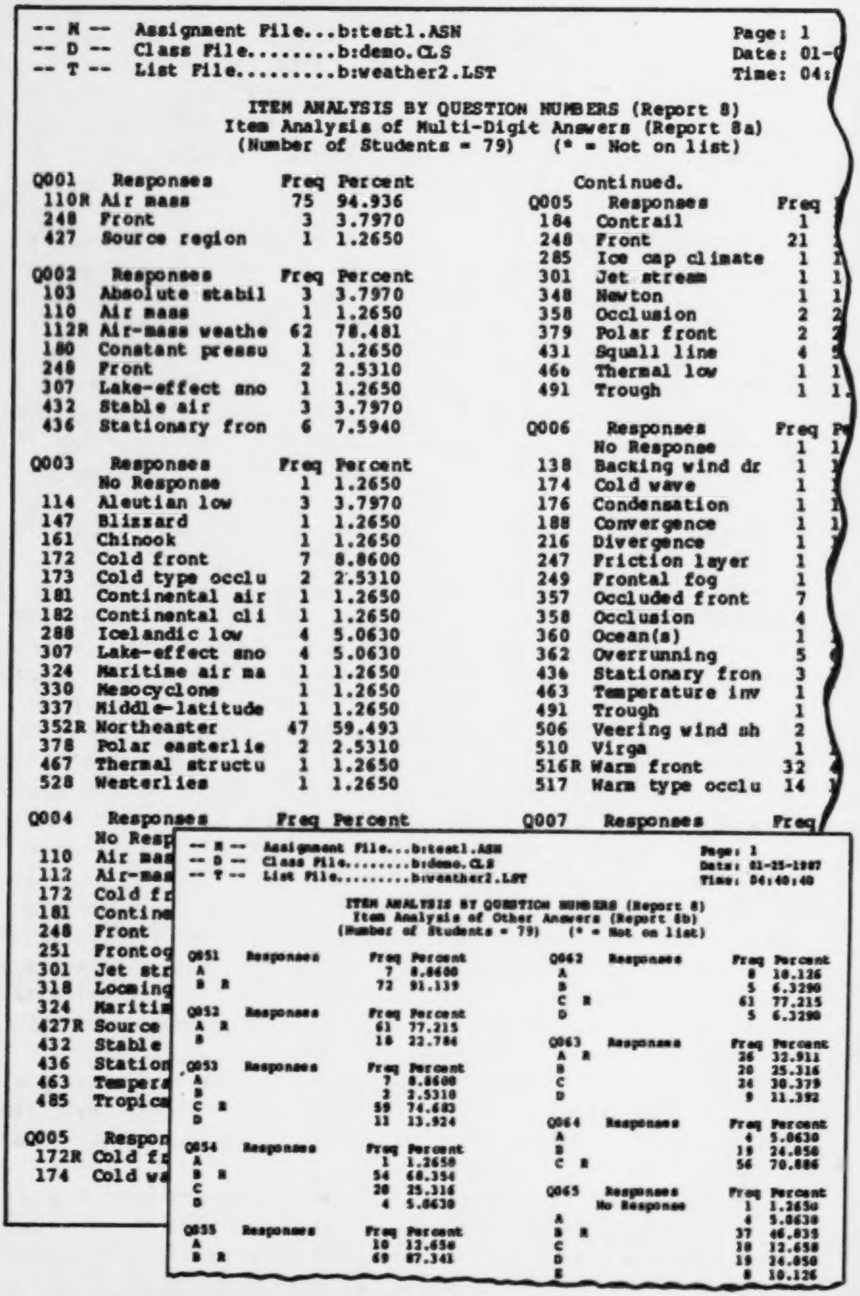
```
MDT4            DIFFICULTY & VALIDITY REPORT

QUESTION   DIFFICULTY SCORE              VALIDITY

      1         .9259                     0.2000
      2         .5556                     0.6895
      3         .8395                     0.5000
      4         .7037                     0.4947
      5         .8025                     0.2947
      6         .8889                     0.2974
      7         .6173                     0.4421
      8         .8642                     0.4500
      9         .5679                     0.5395
     10         .7284                     0.5974
     11         .5679                     0.5842
     12         .5185                     0.5921
     13         .3457                     0.6342
     14         .0123                    -0.0500
     15         .6914                     0.6474
     16         .5062                     0.6447
     17         .7531                     0.5500
     18         .4074                     0.7921
     19         .6049                     0.3868
     20         .5185                     0.7921
     21         .2346                     0.3184
     22         .8025                     0.3000
     23         .4691                     0.6342
     24         .4691                     0.7447
     25         .4198                     0.5368
     26         .6296                     0.3921
     27         .6420                     0.5474
```

The discrimination index is another statistic which helps identify which questions provide the best differential between good and poor students. The rationale of the discrimination index is that students who get high scores on the test should be answering correctly the question being analyzed. The students with the lowest scores, likewise, should be missing the question most frequently. The students in the middle fifty percent are excluded from this analysis. A discrimination index of 1.0 indicates that all students who received high scores on the test also correctly answered a particular question while students who received low scores were the ones who missed tne question. A validity index of 0.0 indicates an equal balance. A negative validity index (minimum value being -1.0) indicates that the higher scoring students were missing a question that the lower scoring students were answering correctly. This latter case indicates the question was possibly misleading or had other problems. Since the total scores on the test are not independent of the scores on the individual questions, the discrimination index has limitations if the number of students or number of questions is small. To be truly useful in evaluating questions, discrimination index values should be obtained for the same questions given to large numbers of students or to multiple sections of a course. The usefulness of the discrimination index is at the discretion of the individual instructor; the MDT software provides the calculations.

7.5.4 Item Analysis: Item analysis has been a standard computer output for several decades and demonstrates why computer scoring improves feedback more than hand scoring of identical tests. For every question there is a printed list of every code number for answers selected by the students, the number and the percentage of students who selected each answer. In addition, the computer prints the word or term that corresponds with each of those code numbers (Figure 7-4). This unique and extremely useful feature requires the computer readable long-list file to be accessible by the computer program. By quickly seeing all of the responses selected by students that missed the question, the instructor can check to see if any of those responses could have been a legitimate answer.

The item analysis also reveals responses which could be the result of miscoding. In the case of miscoding, perhaps the student does not deserve to earn the points,

Figure 7-4 Item Analysis from MDT (Microcomputer)



```
-- M --  Assignment File...b:test1.ASN                                Page: 1
-- D --  Class File........b:demo.CLS                                 Date: 01-
-- T --  List File.........b:weather2.LST                             Time: 04:

              ITEM ANALYSIS BY QUESTION NUMBERS (Report 8)
            Item Analysis of Multi-Digit Answers (Report 8a)
            (Number of Students = 79)    (* = Not on list)

Q001    Responses          Freq Percent          Continued.
 110R Air mass               75  94.936         Q005    Responses          Freq
 248  Front                   3  3.7970          184   Contrail               1
 427  Source region           1  1.2650          248   Front                 21
                                                 285   Ice cap climate        1
Q002    Responses          Freq Percent          301   Jet stream             1
 103  Absolute stabil         3  3.7970          348   Newton                 1
 110  Air mass                1  1.2650          358   Occlusion              2
 112R Air-mass weathe        62  78.481          379   Polar front            2
 180  Constant pressu         1  1.2650          431   Squall line            4
 248  Front                   2  2.5310          466   Thermal low            1
 307  Lake-effect sno         1  1.2650          491   Trough                 1
 432  Stable air              3  3.7970
 436  Stationary fron         6  7.5940         Q006    Responses          Freq
                                                       No Response            1
Q003    Responses          Freq Percent          138   Backing wind dr        1
      No Response             1  1.2650          174   Cold wave              1
 114  Aleutian low            3  3.7970          176   Condensation           1
 147  Blizzard                1  1.2650          188   Convergence            1
 161  Chinook                 1  1.2650          216   Divergence             1
 172  Cold front              7  8.8600          247   Friction layer         1
 173  Cold type occlu         2  2.5310          249   Frontal fog            1
 181  Continental air         1  1.2650          357   Occluded front         7
 182  Continental cli         1  1.2650          358   Occlusion              4
 288  Icelandic low           4  5.0630          360   Ocean(s)               1
 307  Lake-effect sno         4  5.0630          362   Overrunning            5
 324  Maritime air ma         1  1.2650          436   Stationary fron        3
 330  Mesocyclone             1  1.2650          463   Temperature inv        1
 337  Middle-latitude         1  1.2650          491   Trough                 1
 352R Northeaster            47  59.493          506   Veering wind sh        2
 378  Polar easterlie         2  2.5310          510   Virga                  1
 467  Thermal structu         1  1.2650          516R  Warm front            32
 528  Westerlies              1  1.2650          517   Warm type occlu       14

Q004    Responses          Freq Percent         Q007    Responses          Freq
      No Resp
 110  Air mas
 112  Air-mas
 172  Cold fr
 181  Contine
 248  Front
 251  Frontog
 301  Jet str
 318  Looming
 324  Maritim
 427R Source
 432  Stable
 436  Station
 463  Tempera
 485  Tropica

Q005    Respon
 172R Cold fr
 174  Cold wa
```

```
-- M --  Assignment File...b:test1.ASN                          Page: 1
-- D --  Class File........b:demo.CLS                           Date: 01-25-1987
-- T --  List File.........b:weather2.LST                       Time: 04:40:40

               ITEM ANALYSIS BY QUESTION NUMBERS (Report 8)
                 Item Analysis of Other Answers (Report 8b)
               (Number of Students = 79)    (* = Not on list)

Q051     Responses          Freq Percent      Q062     Responses          Freq Percent
 A                             7  8.8600       A                             8  10.126
 B  R                         72  91.139       B                             5  6.3290
                                               C  R                         61  77.215
Q052     Responses          Freq Percent       D                             5  6.3290
 A  R                         61  77.215
 B                            18  22.784      Q063     Responses          Freq Percent
                                               A  R                         26  32.911
Q053     Responses          Freq Percent       B                            20  25.316
 A                             7  8.8600       C                            24  30.379
 B                             2  2.5310       D                             9  11.392
 C  R                         59  74.683
 D                            11  13.924      Q064     Responses          Freq Percent
                                               A                             4  5.0630
Q054     Responses          Freq Percent       B                            19  24.050
 A                             1  1.2650       C  R                         56  70.886
 B  R                         54  68.354
 C                            20  25.316      Q065     Responses          Freq Percent
 D                             4  5.0630               No Response           1  1.2650
                                               A                             4  5.0630
Q055     Responses          Freq Percent       B  R                         37  46.835
 A                            10  12.658       C                            10  12.658
 B  R                         69  87.341       D                            19  24.050
                                               E                             8  10.126
```

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but that is at the discretion of the instructor. A specific example could be when the scanner has processed an answer like "2 *" when the correct answer was 238. This indicates the student correctly marked the first 2 but then had both of the digits from the tens and ones columns in the ones column. A three and an eight (or any multiple marks) in a column result in an asterisk for invalid marks being printed. The blank space in the tens column shows that no mark was made. If the instructor wants to know which student gave such a strange answer, he/she can look at the full listing (dump) in the appropriate column for the question and find which student gave the answer under consideration. A quick check of the small boxes for that question on the answer form will clarify the student's intended answer. Errors by students when marking and by instructors when grading have occurred in the past with other grading systems and will occur in the future. The improvements offered by the MDT software make it easier to detect and correct such errors.

Instructors should not be surprised at extremely illogical answers in the listing of the responses from the students. These answers can be from wild guessing or incomplete answers. A student could start to encode one answer, then realize it is incorrect and not finish encoding anything else because he/she does not know the correct answer. On the other hand, some illogical answers could be a signal to check code numbers. For example, in one test a student had difficulty encoding the right answers. The student later presented his individual feedback sheet and explained where the marking errors occurred. It was probably a bad case of test anxiety. In the test, the student left off the final digit for the answer Dead Sea #466. The result was #460 the Colorado River, which is nowhere near the same region of the world nor relevant to the particular question. In addition, the student had difficulties marking the cells for 9s and 8s on the answer sheet. Since two out of three of the digits were correct and the alternative answers as encoded were totally illogical, and because of the student's generally good performance on other aspects of the test, a grade revision was allowed. This student was more careful in subsequent examinations and the problem did not reoccur.

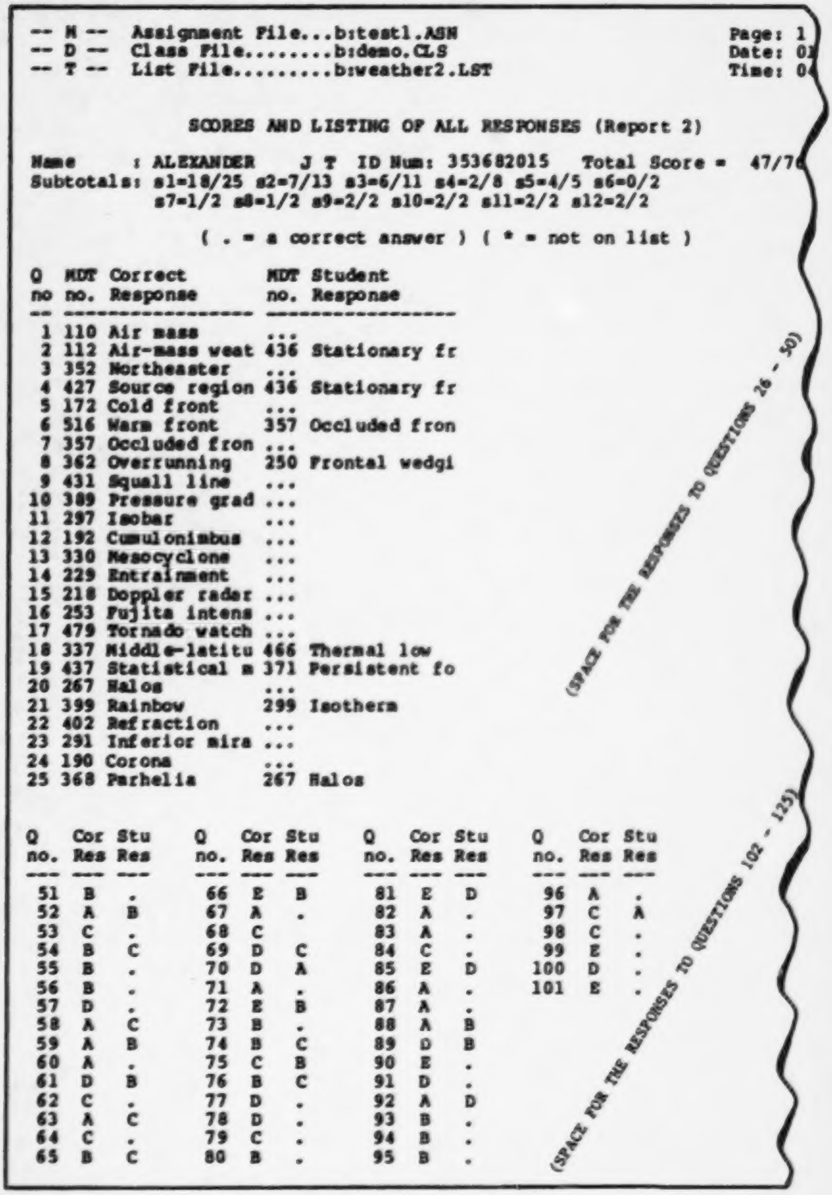
Sometimes students place a correct answer in the wrong column, which is an incorrect response. There is certainly no obligation on the part of the professor to allow points for such errors. On the other hand, pointing out those occurences to the students should help them to realize that they are possibly committing similar errors elsewhere on tests in other courses. In five-choice questions there is no procedure for granting students any additional points, yet many students are probably obtaining lower grades than normal because of this inflexible aspect of computer-scored grading. This fact certainly does not nullify the value of using computerized methods, but it is definitely something that should be called to the attention of the students.

7.5.5 Individual Reports for Each Student: Instructors may request individual reports (a printout sheet for each student) with test results (Figure 7-5). This option gives a considerable volume of paper and should not be utilized unless you intend to hand these sheets back to the students. These sheets are of use to a student because the correct word answer for each question is printed side by side with the student's word response. This usually enables students to recall the question, something they are not able to do when they are simply told their answer was "b" for Question 14 but the correct response was "c". With the MDT System the student is told his or her answer for Question 6 was "287 Churchill, Winston" and the correct answer was "463 Roosevelt, Franklin". The student is then well aware of the material covered in the question. Since the objective of education is student learning, this enhanced positive feedback is considered to be a major advantage of MDT multi-digit testing.

It should be noted that the individual sheets are not particularly helpful as study guides to students in future semesters. To know that Roosevelt was the answer to some unknown question is not much of a hint. Other answers might be more revealing, so using the exact same test is discouraged for at least a semester or two. However, the MDT innovation greatly facilitates question generation and exam modification.

An additional advantage of the individual feedback sheets is that each student is able to review what the scanner and computer have recorded as the response marks. Some students are overly concerned that they might be marking their sheets erroneously. The opportunity to see how the computer has read their marks is helpful to these students. In addition, each student thereby assists the instructor in the review of the quality of the marks. For

Figure 7-5 Individual Student Report with Listed Answers



```
-- M --  Assignment File...b:test1.ASN                              Page: 1
-- D --  Class File........b:demo.CLS                               Date: 0
-- T --  List File.........b:weather2.LST                           Time: 0

                SCORES AND LISTING OF ALL RESPONSES (Report 2)

Name      : ALEXANDER    J T  ID Num: 353682015   Total Score =  47/7
Subtotals: s1=18/25 s2=7/13 s3=6/11 s4=2/8 s5=4/5 s6=0/2
           s7=1/2 s8=1/2 s9=2/2 s10=2/2 s11=2/2 s12=2/2

                 ( . = a correct answer ) ( * = not on list )

Q  MDT Correct         MDT Student
no no. Response        no. Response
-- ---------------- ----------------
 1 110 Air mass        ...
 2 112 Air-mass weat 436 Stationary fr
 3 352 Northeaster     ...
 4 427 Source region 436 Stationary fr
 5 172 Cold front      ...
 6 516 Warm front      357 Occluded fron
 7 357 Occluded fron ...
 8 362 Overrunning     250 Frontal wedgi
 9 431 Squall line     ...
10 389 Pressure grad ...
11 297 Isobar          ...
12 192 Cumulonimbus    ...
13 330 Mesocyclone     ...
14 229 Entrainment     ...
15 218 Doppler radar ...
16 253 Fujita intens ...
17 479 Tornado watch ...
18 337 Middle-latitu 466 Thermal low
19 437 Statistical m 371 Persistent fo
20 267 Halos           ...
21 399 Rainbow         299 Isotherm
22 402 Refraction      ...
23 291 Inferior mira ...
24 190 Corona          ...
25 368 Parhelia        267 Halos

                                        (SPACE FOR THE RESPONSES TO QUESTIONS 26 - 50)

Q    Cor Stu      Q    Cor Stu      Q    Cor Stu      Q    Cor Stu
no.  Res Res      no.  Res Res      no.  Res Res      no.  Res Res
---  --- ---      ---  --- ---      ---  --- ---      ---  --- ---
 51   B   .        66   E   B        81   E   D        96   A   .
 52   A   B        67   A   .        82   A   .        97   C   A
 53   C   .        68   C            83   A   .        98   C   .
 54   B   C        69   D   C        84   C   .        99   E   .
 55   B   .        70   D   A        85   E   D       100   D   .
 56   B   .        71   A   .        86   A   .       101   E   .
 57   D   .        72   E   B        87   A   .
 58   A   C        73   B   .        88   A   B
 59   A   B        74   B   C        89   D   B
 60   A   .        75   C   B        90   E   .
 61   D   B        76   B   C        91   D   .
 62   C   .        77   D   .        92   A   D
 63   A   C        78   D   .        93   B   .
 64   C   .        79   C   .        94   B   .
 65   B   C        80   B   .        95   B   .

                                        (SPACE FOR THE RESPONSES TO QUESTIONS 102 - 125)
```

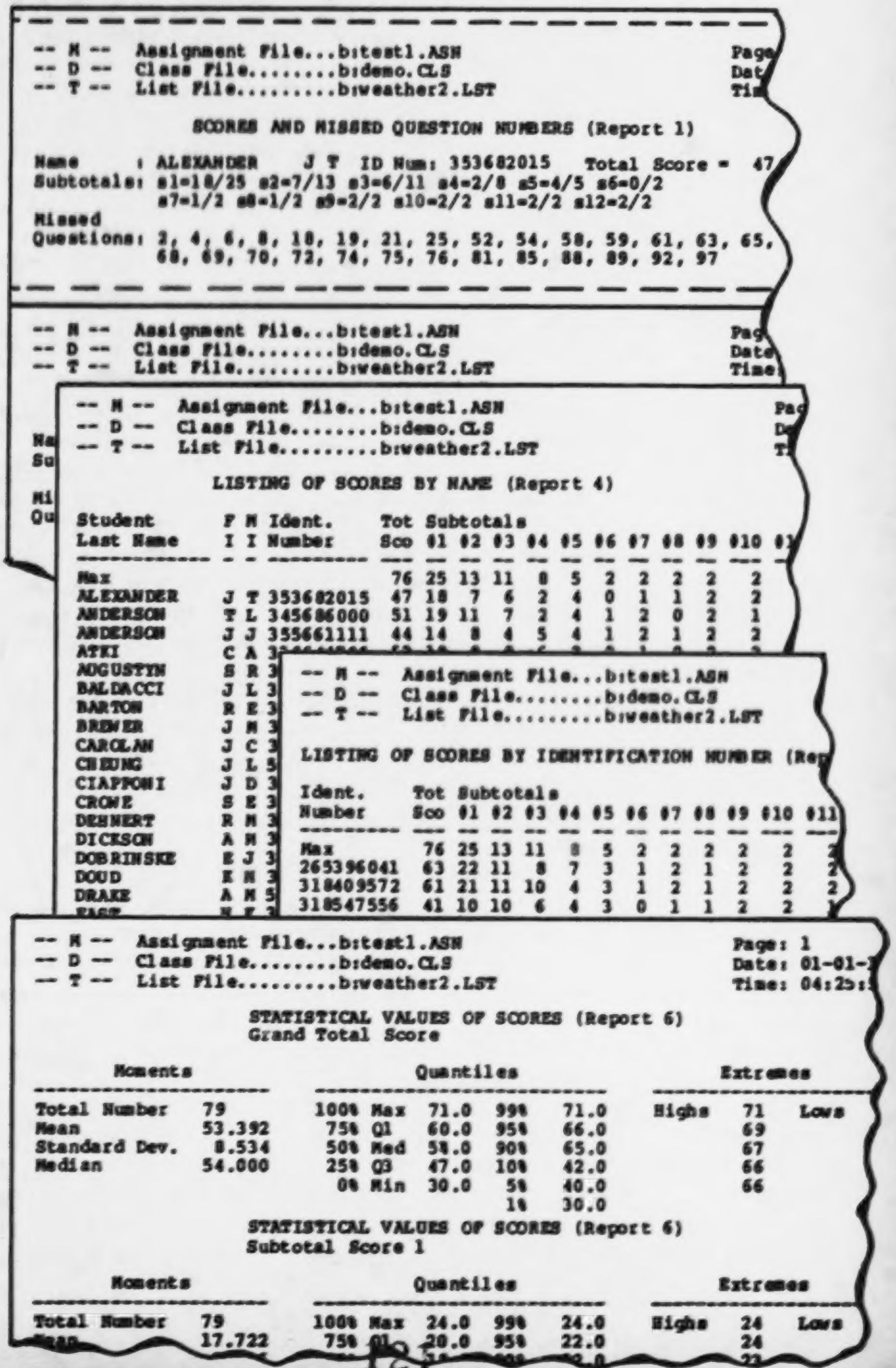
example, if a student has marked incorrectly with double marks in one column and no mark in another, this will be revealed on the printout. Students can then request to see the actual answer form upon which the three-digit numerals should be written correctly in the small boxes at the head of each of the response areas. In such cases, most instructors would give the student the additional points while also strongly reminding the student that more care should be taken in marking the answer form. In these situations, the number of times that students mis-mark should reduce dramatically as they take more care in their marking. It should be noted that miscoding is actually a relatively infrequent error.

The individual sheet for each student and the listings for posting also contain the total and the part scores. When the instructor informs the students of the objective of each of the various parts, the part scores can become extremely useful for the student to identify areas where he/she has performed above or below average in comparison with the entire class. For example, some students might do well on the multiple choice parts of the test, but not on the recall questions. Likewise, the part scores might indicate groupings of easy questions and hard questions which can give significant diagnostic information to students as well as the instructors.

The printing of part scores, individual feedback sheets and word labels are requested on a control sheet when using the mainframe MDT4 program. Section 6.8, Figure 6-1 and Appendix 1 show how these features are requested. On the MicroMDT program, the control is via menus on the microcomputer screen.

7.5.6 Listings for Postings, Grade Book and Rank Order: The three listings mentioned here are basically the same (see Figure 7-6) except for cosmetic modifications to suit different purposes. In all cases, the total scores and the part scores are shown along with the identification number for each student. On the list for posting, the page is organized by numerical order of the identification number. This list can be displayed so that students can find their grades on a test. (Note: Two copies of the list for posting are generated so they can be placed in two locations. Alternatively, one may be held in reserve in case the other listing is torn down or thrown away by accident.) The grade book report has student names and is organized in

Figure 7-6 Printout Reports from Scored Tests



```
-- M --  Assignment File...b:test1.ASN                             Page
-- D --  Class File........b:demo.CLS                              Dat
-- T --  List File.........b:weather2.LST                          Ti

            SCORES AND MISSED QUESTION NUMBERS (Report 1)

Name      : ALEXANDER    J T  ID Num: 353682015   Total Score =  47
Subtotals: s1=18/25 s2=7/13 s3=6/11 s4=2/8 s5=4/5 s6=0/2
           s7=1/2 s8=1/2 s9=2/2 s10=2/2 s11=2/2 s12=2/2
Missed
Questions: 2, 4, 6, 8, 18, 19, 21, 25, 52, 54, 58, 59, 61, 63, 65,
           68, 69, 70, 72, 74, 75, 76, 81, 85, 88, 89, 92, 97
```

```
-- M --  Assignment File...b:test1.ASN                             Pag
-- D --  Class File........b:demo.CLS                              Date
-- T --  List File.........b:weather2.LST                          Time:

Na
Su

Mi
Qu
```

```
-- M --  Assignment File...b:test1.ASN                             Pa
-- D --  Class File........b:demo.CLS                              D
-- T --  List File.........b:weather2.LST                          T

            LISTING OF SCORES BY NAME (Report 4)

Student       F M Ident.     Tot Subtotals
Last Name     I I Number     Sco #1 #2 #3 #4 #5 #6 #7 #8 #9 #10 #1
------------- - - ---------  --- -- -- -- -- -- -- -- -- -- --- -
Max                           76 25 13 11  8  5  2  2  2  2   2
ALEXANDER     J T 353682015   47 18  7  6  2  4  0  1  1  2   2
ANDERSON      T L 345686000   51 19 11  7  2  4  1  2  0  2   1
ANDERSON      J J 355661111   44 14  8  4  5  4  1  2  1  2   2
ATKI          C A 3
AUGUSTYN      S R 3
BALDACCI      J L 3
BARTON        R E 3
BREWER        J M 3
CAROLAN       J C 3
CHEUNG        J L 5
CIAPPONI      J D 3
CROWE         S E 3
DEHNERT       R M 3
DICKSON       A M 3
DOBRINSKE     E J 3
DOUD          E M 3
DRAKE         A M 5
```

```
-- M --  Assignment File...b:test1.ASN
-- D --  Class File........b:demo.CLS
-- T --  List File.........b:weather2.LST

LISTING OF SCORES BY IDENTIFICATION NUMBER (Re

Ident.     Tot Subtotals
Number     Sco #1 #2 #3 #4 #5 #6 #7 #8 #9 #10 #11
---------  --- -- -- -- -- -- -- -- -- -- --- ---
Max         76 25 13 11  8  5  2  2  2  2   2   2
265396041   63 22 11  8  7  3  1  2  1  2   2   2
318409572   61 21 11 10  4  3  1  2  1  2   2   2
318547556   41 10 10  6  4  3  0  1  1  2   2   1
```

```
-- M --  Assignment File...b:test1.ASN                             Page: 1
-- D --  Class File........b:demo.CLS                              Date: 01-01-
-- T --  List File.........b:weather2.LST                          Time: 04:25:

                STATISTICAL VALUES OF SCORES (Report 6)
                Grand Total Score

      Moments                      Quantiles                       Extremes
----------------------    ----------------------------      ----------------
Total Number    79        100% Max  71.0   99%    71.0      Highs   71   Lows
Mean            53.392     75% Q1   60.0   95%    66.0              69
Standard Dev.    8.534     50% Med  54.0   90%    65.0              67
Median          54.000     25% Q3   47.0   10%    42.0              66
                            0% Min  30.0    5%    40.0              66
                                            1%    30.0
                STATISTICAL VALUES OF SCORES (Report 6)
                Subtotal Score 1

      Moments                      Quantiles                       Extremes
----------------------    ----------------------------      ----------------
Total Number    79        100% Max  24.0   99%    24.0      Highs   24   Lows
Mean            17.722     75% Q1   20.0   95%    22.0              24
```

alphabetical order. It is very similar to the first portion of the full listing (dump) which was discussed earlier. However, it appears in a condensed format more suitable for preserving grades, as in a grade book. (The computerized grade book is discussed in Section 7.6.) The listing by rank order lists students by name according to their total score on the test. From this list a teacher can more readily identify which students were faring particularly well or poorly on a given test.

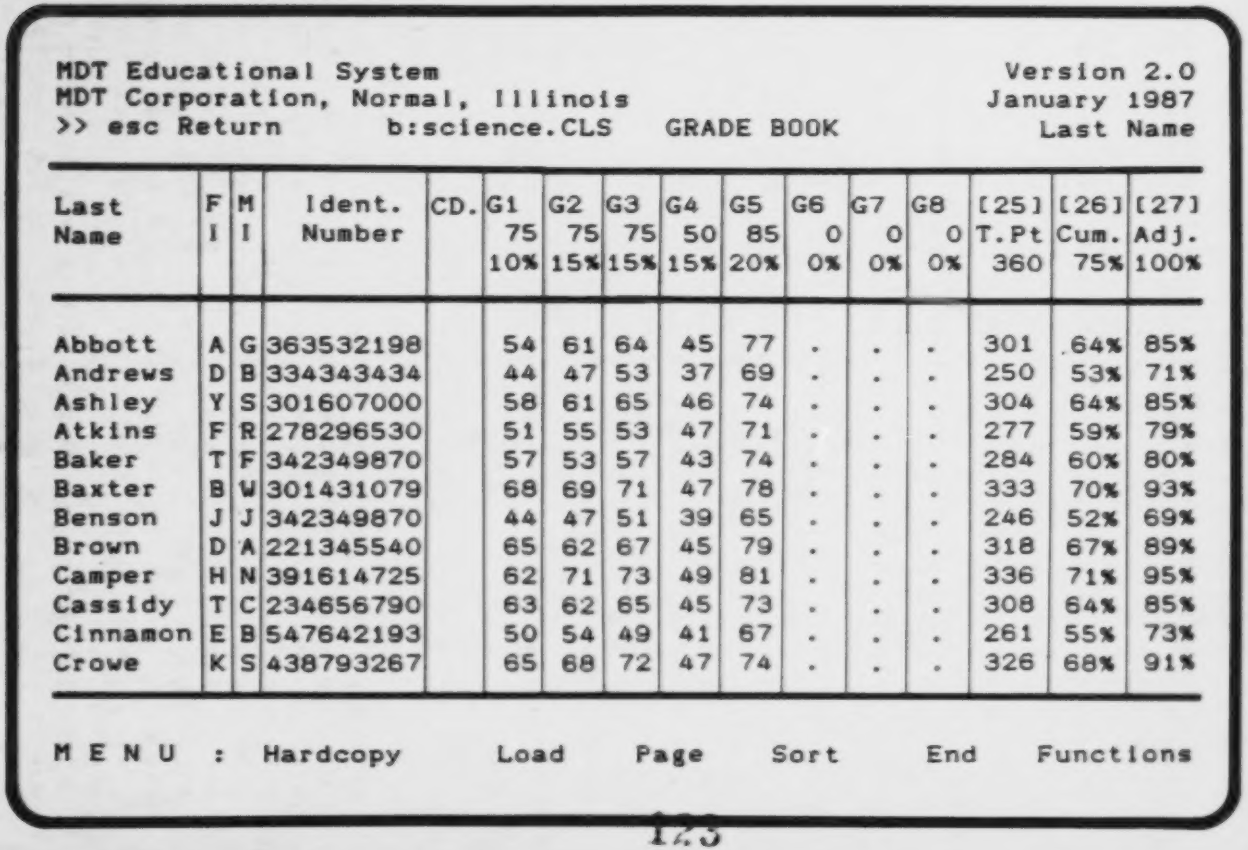
7.6 Computer-Managed Grade Books

A computerized grade book is a handy feature. For the mainframe computer programs, a modification is available which saves the final scores and identification numbers on a disc file. Then a grade book program at the user school can incorporate the test scores for cumulative grading.

The MicroMDT software contains its own grade book. Once scoring is complete, a few menu-guided keystrokes will transfer a set of test scores into an electronic grade book. Up to twenty-four scores (in columns) for as many as three hundred students (in rows) can be recorded during a course (Figure 7-7). The point value of each part and its percentage of the final total course points for each column can be independently specified and changed as desired. The program also allows manual entries, editing, deleting and printing. The printouts can be by class or individual student (Figure 7-8).

7.7 The Short Answer SA (Essay) Feature

For a long time instructors have wanted to utilize the capabilities of computers to facilitate the scoring of subjective portions of educational testing. This is still not possible, but once an item has been scored manually, an MDT answer form plus a scanner can greatly facilitate the recording of subjective scores for analysis and better feedback. Machine readable spaces (called the "SA" feature in the MDT Educational System) are provided for the instructor to mark directly on the MDT answer the subjective scores for short answer/essay questions. These scores enter the MDT system through an optical scanner. This method can be used in cases where the students have been asked to make calculations, show formulas, draw diagrams, write full essays or give short sentence answers (see the example in



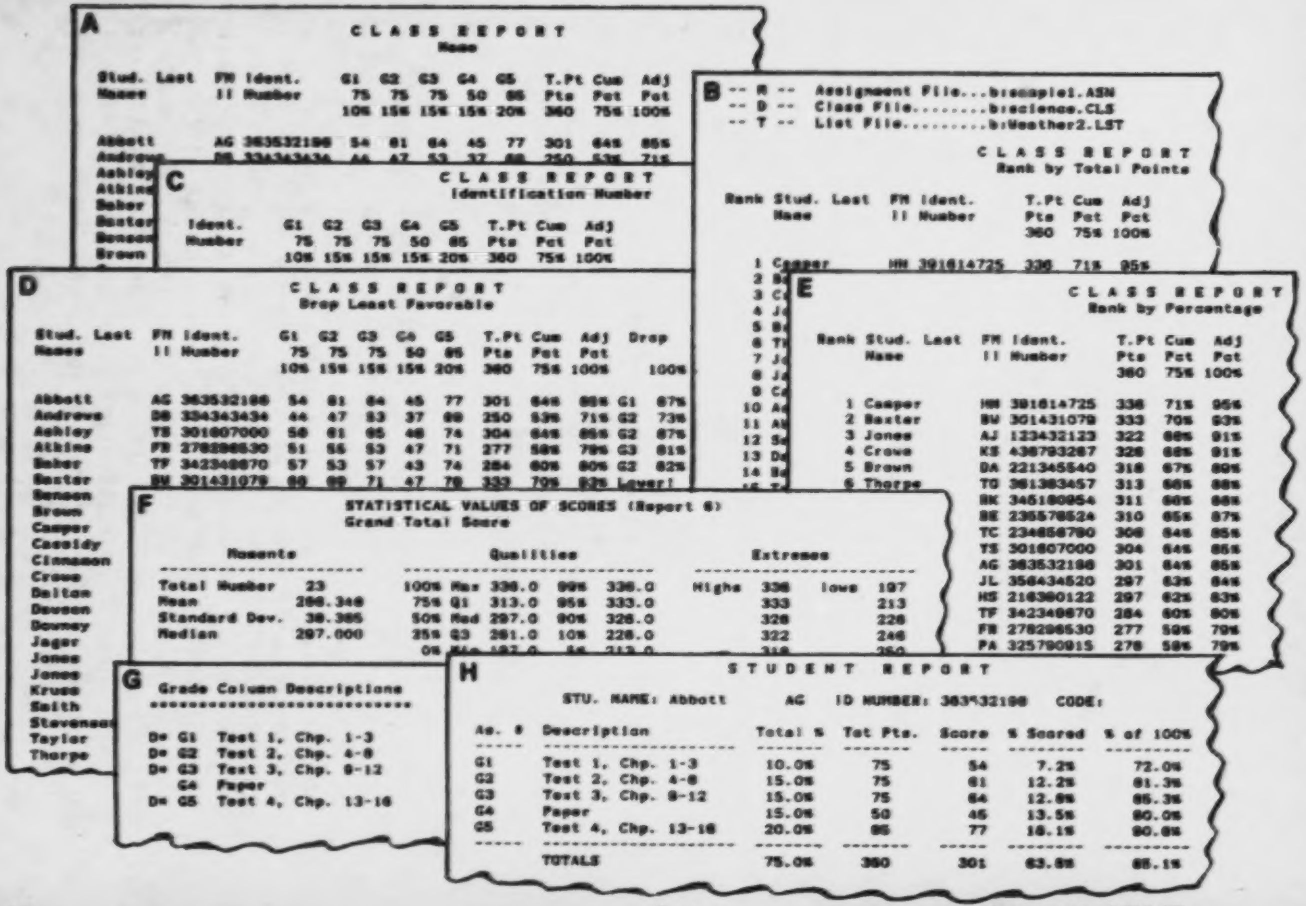
```
MDT Educational System                                    Version 2.0
MDT Corporation, Normal, Illinois                        January 1987
>> esc Return      b:science.CLS   GRADE BOOK               Last Name

Last     |F|M|  Ident.  |CD.|G1  |G2  |G3  |G4  |G5  |G6  |G7  |G8  |[25] |[26]|[27]
Name     |I|I|  Number  |   |  75|  75|  75|  50|  85|   0|   0|   0|T.Pt |Cum.|Adj.
         | | |          |   | 10%| 15%| 15%| 15%| 20%|  0%|  0%|  0%|  360| 75%|100%

Abbott   |A|G|363532198 |   |  54|  61|  64|  45|  77|  . |  . |  . |  301| 64%| 85%
Andrews  |D|B|334343434 |   |  44|  47|  53|  37|  69|  . |  . |  . |  250| 53%| 71%
Ashley   |Y|S|301607000 |   |  58|  61|  65|  46|  74|  . |  . |  . |  304| 64%| 85%
Atkins   |F|R|278296530 |   |  51|  55|  53|  47|  71|  . |  . |  . |  277| 59%| 79%
Baker    |T|F|342349870 |   |  57|  53|  57|  43|  74|  . |  . |  . |  284| 60%| 80%
Baxter   |B|W|301431079 |   |  68|  69|  71|  47|  78|  . |  . |  . |  333| 70%| 93%
Benson   |J|J|342349870 |   |  44|  47|  51|  39|  65|  . |  . |  . |  246| 52%| 69%
Brown    |D|A|221345540 |   |  65|  62|  67|  45|  79|  . |  . |  . |  318| 67%| 89%
Camper   |H|N|391614725 |   |  62|  71|  73|  49|  81|  . |  . |  . |  336| 71%| 95%
Cassidy  |T|C|234656790 |   |  63|  62|  65|  45|  73|  . |  . |  . |  308| 64%| 85%
Cinnamon |E|B|547642193 |   |  50|  54|  49|  41|  67|  . |  . |  . |  261| 55%| 73%
Crowe    |K|S|438793267 |   |  65|  68|  72|  47|  74|  . |  . |  . |  326| 68%| 91%

M E N U  :  Hardcopy     Load     Page     Sort      End     Functions
```

Figure 7-7 MDT Grade Book on Microcomputers



```
A                         C L A S S   R E P O R T
                                    Name

Stud. Last   FM Ident.     G1   G2   G3   G4   G5    T.Pt Cum  Adj
Name         II Number     75   75   75   50   85    Pts  Pct  Pct
                          10%  15%  15%  15%  20%    360  75%  100%

Abbott       AG 383532186  54   61   64   45   77    301  64%  85%
Andrews      DB 334343434  44   47   53   37   69    250  53%  71%
Ashle
Atkin
Baker
Baxter
Benso
Brown
```

```
C                         C L A S S   R E P O R T
                          Identification Number

Ident.        G1   G2   G3   G4   G5    T.Pt Cum  Adj
Number        75   75   75   50   85    Pts  Pct  Pct
             10%  15%  15%  15%  20%    360  75%  100%
```

```
B -- R --  Assignment File...b:sample1.ASN
  -- D --  Class File........b:science.CLS
  -- T --  List File.........b:Weather2.LST

                              C L A S S   R E P O R T
                               Rank by Total Points

Rank Stud. Last   FM Ident.      T.Pt Cum  Adj
     Name         II Number      Pts  Pct  Pct
                                 360  75%  100%

   1 Camper       HM 391614725   336  71%  95%
   2 B
   3 C
   4 J
   5 B
   6 T
   7 J
   8 J
   9 C
  10 A
  11 A
  12 S
  13 D
  14 B
```

```
D                         C L A S S   R E P O R T
                          Drop Least Favorable

Stud. Last   FM Ident.     G1   G2   G3   G4   G5    T.Pt Cum  Adj   Drop
Names        II Number     75   75   75   50   85    Pts  Pct  Pct
                          10%  15%  15%  15%  20%    360  75%  100%      100%

Abbott       AG 383532186  54   61   64   45   77    301  64%  85% G1   87%
Andrews      DB 334343434  44   47   53   37   69    250  53%  71% G2   73%
Ashley       TS 301607000  58   61   65   46   74    304  64%  85% G2   87%
Atkins       FR 278286530  51   55   53   47   71    277  58%  79% G3   81%
Baker        TF 342348870  57   53   57   43   74    284  60%  80% G2   82%
Baxter       BW 301431079  68   69   71   47   78    333  70%  93% Lower!
Benson
Brown
Camper
Cassidy
Cinnamon
Crowe
Dalton
Dawson
Downey
Jager
Jones
Jones
Kruse
Smith
Stevenso
Taylor
Thorpe
```

```
E                         C L A S S   R E P O R T
                             Rank by Percentage

Rank Stud. Last   FM Ident.      T.Pt Cum  Adj
     Name         II Number      Pts  Pct  Pct
                                 360  75%  100%

   1 Camper       HM 391614725   336  71%  95%
   2 Baxter       BW 301431079   333  70%  93%
   3 Jones        AJ 123432123   322  68%  91%
   4 Crowe        KS 438793287   328  68%  91%
   5 Brown        DA 221345540   318  67%  89%
   6 Thorpe       TG 361383457   313  66%  88%
                  RK 345180854   311  66%  88%
                  BE 235578524   310  65%  87%
                  TC 234656780   308  64%  85%
                  TS 301607000   304  64%  85%
                  AG 383532186   301  64%  85%
                  JL 358434520   297  63%  84%
                  HS 216380122   297  62%  83%
                  TF 342348870   284  60%  80%
                  FR 278286530   277  58%  79%
                  PA 325790915   278  58%  79%
```

```
F              STATISTICAL VALUES OF SCORES (Report 6)
               Grand Total Score

      Moments                    Qualities                      Extremes
---------------------    -------------------------    -------------------------
Total Number    23       100% Max 336.0   99%  336.0   Highs  336    lows   197
Mean           288.348    75% Q1  313.0   95%  333.0          333           213
Standard Dev.   38.385    50% Med 297.0   90%  328.0          328           228
Median         297.000    25% Q3  281.0   10%  228.0          322           246
```

```
G  Grade Column Descriptions
   ****************************

   D= G1  Test 1, Chp. 1-3
   D= G2  Test 2, Chp. 4-8
   D= G3  Test 3, Chp. 9-12
      G4  Paper
   D= G5  Test 4, Chp. 13-16
```

```
H                      S T U D E N T   R E P O R T

        STU. NAME: Abbott        AG   ID NUMBER: 383°32186   CODE:

As. #  Description            Total %  Tot Pts.  Score  % Scored  % of 100%
-----  ---------------------  -------  --------  -----  --------  ---------
G1     Test 1, Chp. 1-3        10.0%      75       54      7.2%      72.0%
G2     Test 2, Chp. 4-8        15.0%      75       61     12.2%      81.3%
G3     Test 3, Chp. 9-12       15.0%      75       64     12.8%      85.3%
G4     Paper                   15.0%      50       45     13.5%      90.0%
G5     Test 4, Chp. 13-16      20.0%      85       77     18.1%      90.6%
-----  ---------------------  -------  --------  -----  --------  ---------
       TOTALS                  75.0%     360      301     63.8%      85.1%
```

Figure 7-8 Printout Reports from MDT Grade Book

BEST COPY AVAILABLF

Section 1.2 and Figure 1-5). The students can write their answers on separate pieces of paper or within special spaces designed for SA answers on the back and bottom of MDT answer cards and sheets.

With this feature many instructors who have relied exclusively on objective tests can now easily diversify to include ten to forty points for subjective questions. This is a major step towards the promotion of written (subjective) answers and higher order learning by students. Likewise, instructors who have primarily used subjective tests can now easily ask a few objective questions using machine-scored fill-in-the-blank methods by placing the scores for the subjective parts on the SA areas of the MDT answer sheets, all of the test results can be tallied, statistically analyzed and entered into the grade book. **When coupled with the fill-in-the-blank questioning format available through the MDT innovation, the SA feature opens to the instructor the advantages of computer assistance for the full spectrum of educational testing.**

These innovations from the Multi-Digit Technologies Corporation will stimulate greater diversity in educational measurement and evaluation. The objective is not to reduce teachers' work loads, but to modify these work loads so the instructor is devoting his/her energies where best utilized. Instead of performing mundane and repetitious tasks that can be handled by computers, instructors can spend time on lesson preparation, individual contact with students, research or other academic activities. The ultimate objective of all this is the improvement of educational quality.

7.8 Instant Scoring

A major aid in the learning cycle is faster feedback to students of what they answered correctly and incorrectly. The fastest methods are one-on-one teacher/student interaction and interactive on-line computer assisted instruction. Both of these methods are relatively costly in terms of time or equipment. The next fastest and extremely cost effective feedback comes from **computer scoring of tests before the students leave the classroom.** Instant scoring has been available to some teachers who could make a small optical mark reader (OMR) into their classroom. These have generally been the small stand-alone OMR models without any extra advantages and processing power from microcomputers. If the goal of education is student learning, then instant scoring with its many pedagogical variations should become standard practice and economically feasible in the classroom. It will be many years before every student has simultaneous access to a computer. But the availability of low cost scanners is only a short time away. The Micro-MDT program includes two printout options for instant feedback. A small cart would wheel the system to any classroom. The Multi-Digit Technologies Corporation is continuing its work in this aspect of testing. Reductions in the cost of computer and scanner hardware, software and "paperware" are objectives of the MDT Corporation. Specific information is available from the company.

7.9 Conclusion

This chapter and the three preceding ones focus on practical issues about utilization of MDT multi-digit testing by classroom teachers. Most of the topics are clear to experienced instructors; other topics will become clear with use. The more technical operational issues are in the MDT Operations Manual provided with the software.

Knowing now the various features and capabilities of the MDT Education System, we turn to questions of "Why should this method be used?" and "How can it benefit both students and instructors?" Various educational issues concerning the MDT technique, with comparisons to other test formats, are discussed in the final chapters which form Part C of this book.

PART C

Educational Issues

Discussions about innovations in educational matters must be directed to a wide range of audiences. Academic educational specialists want documented evidence with theory-based reasoning; lay readers desire concise summaries with authoritative statements about the impact of an innovation upon their children and schools. Many readers, such as school administrators and teachers, want both. Part C is a mixture of both. The readers are asked to interpret each section accordingly and to remember that the study of the educational implications of MDT multi-digit testing is still in its infancy. Any discussion of research, administration, theory, cost, educational impact and acceptance raises many exciting questions that remain to be answered.

The five chapters in Part C raise and at least partially answer some questions concerning the educational issues stemming from the MDT innovation. Some specific research results concerning previous work by others and cognitive retention are presented in Chapter Eight. The other chapters discuss demonstrated capabilities and likely educational implications of the MDT Educational System. The issues of training and mastery learning at appropriate academic levels are in Chapter Nine. Chapter Ten presents the possible benefits of the MDT features in relation to time-savings and financial matters. Higher order learning is discussed in Chapter Eleven. The book concludes with the prospects for further development (Chapter Twelve). Many topics in Part C are discussed in concrete terms based on the existing operational status of MDT testing. These chapters foreshadow future research and development by Multi-Digit Technologies Corporation to enhance education through appropriate technology.

The origin and cornerstone upon which the MDT multi-digit testing method is based are fill-in-the-blank (completion) style questions. These are traditionally associated with cognitive (factual) learning and recall. The fact that MDT applications have expanded into other areas is very important. But even without this expansion, the MDT innovation is a viable testing method. For this reason the chapters in Part C mainly deal with the cognitive forms of education. It is only in Chapter Eleven that the higher orders of learning become a major focus.

The MDT method is exciting. Its innovative educational features are coupled with existing electronic technology. The advantages discusses in the following chapters are too apparent to be denied. **The MDT answer bank method could prove to be the most significant innovation in educational measurement in decades.** The only other candidate is on-line (at the keyboard) student interaction with computers, but that development is much more expensive and based on multiple choice "dialog". However, the anticipated educational benefits of the MDT innovation remain largely unsubstantiated; rigorously controlled research needs to be conducted. The classroom experiences have been extremely favorable, but more study of usage is required. This lack of research does not negate the advantages of the MDT method. It simply highlights the need for educational research to catch up with and accompany the actual practice. Please remember the MDT method has been in existence only since early 1983 and has only recently completed the initial development stages.

The five chapters in this part of the book attempt to call attention to the work of others in related situations and also present the limited research conducted thus far with MDT testing. Some portions of these chapters are taken from earlier papers and publications by Paul S. Anderson and several co-authors, as indicated in the bibliography. Acknowledgement of great assistance is given to Professors Miriam Hill, Shamim Naim, William Walters, Jr., and Eileen Kanzler. However, the responsibility for revising or interpreting the various results rests with the author.

The purpose of Part C, and indeed of this entire book, is to make the methods and ideas of MDT multi-digit testing known to others, both laymen and academicians. The issues raised here should be thoroughly evaluated. Everyone is invited and encouraged to participate.

Chapter Eight

Comparative Research on Cognitive Achievement and Retention

8.1 Comparisons Of Testing Methods For Cognitive Learning

The intention of this chapter is not to disqualify already existing testing methods. Each has its special niche. The objective is to point out how the MDT method has its own particular niche to fill in the improvement of education at all levels. The comparisons in this chapter exclude the essay and short answer (full sentence) styles of questions. All others are considered: True/False, multiple choice, matching and fill-in-the-blank, with specific comparisons to the MDT multi-digit method. All comparisons are related to content questions that could be asked fairly on each of the testing methods. Specifically excluded are higher order questions aimed at levels of learning above the application of basic knowledge (discussed in Chapter Eleven).

Each test method must be viewed in both summative and formative situations. A summative test is an end-of-learning evaluation. Formative tests are to further promote ongoing learning. In an oversimplification, a major difference is that formative tests are likely to be returned to the students to assist their studies. The MDT advantage for improved feedback to students and ease of question generation are evident from earlier chapters. These are all factors to be considered in the comparisons of testing methods.

8.1.1 True/False: The "either/or" dichotomous split of True/False gives a fifty-fifty chance of guessing the correct answer. Unlike multiple choice, erroneous alternative answers are not suggested, but often the entire question is incorrect, that is, a false statement. This might be effective in getting a summative (end-of-learning) test result, but it is not very conducive to formative testing (to improve the students learning) unless the graded tests are returned to the students. Then the danger is that the questions are committed to rote memory; the students are waiting for the same (or directly similar) questions to appear on another test. Finally, to make the questions "harder", the tendency is to make the True/False questions "more tricky". In general, these problems are not encountered in the MDT method. Some of the comments in the next paragraph are also applicable to True/False questions.

8.1.2 Multiple Choice: In spite of all its desirable traits, the traditional multiple choice method does receive a considerable amount of criticism. One problem with multiple choice exams concerns the issue of teaching students how to be good test takers. Numerous articles in the press have described courses developed to prepare students to take standardized tests. These courses help students overcome test anxiety and show them how to "beat the system". Among the tricks taught is that tests not prepared by professional test makers can include mistakes in wording that assist students in answering. For example, if an instructor uses the article "an" instead of "a" in a question, the student should select an answer that begins with a vowel, like an apple instead of an pear. In cases where the answer is numerical, it is more likely to be one of the middle three values rather than the highest or lowest value offered in the five choices. There are many other techniques taught to students whereby they can eliminate one to three of the alternatives in a five choice situation. In the end, this "educated selection" process could appropriately be classified as "educated guessing". The use of the term "multiple guess" does have more than a modest amount of relevance to traditional five-choice tests.

Another difficulty with multiple choice tests is the willingness of students to make a selection (that is, a guess) even when no answer is remotely possible. This phenomenon has been studied by Frary (1982). Furthermore, when students do guess, they tend to begin to believe that their selected answer was correct. Unless there is detailed feedback to students to inform them what questions were missed and what the correct answers were to specific questions, the learning process is thwarted. Students tend to select the same answers that they guessed previously. Here the importance of formative testing is again evident.

Many teachers comment that the full impact of a multiple choice test (or any test) can only be obtained when and if the instructor laboriously goes through each of the various questions in a later class and/or distributes the test with correct answers to the students. If this is done, a tremendous burden is placed upon the instructor to develop new, equal and high quality questions for future tests. Otherwise, future students can merely study a collection of questions and five alternative answers from past tests to obtain good scores without actually doing the full learning required. The stories of students passing courses based on studying test files in fraternity houses are too common to be ignored.

One of the tasks of a test is the differentiation of students by test performance in comparison with other students, thereby attaining the rank order of the students for grading on a curve. However, another purpose is to see how much the students actually know and retain in comparison to the expectations of the instructor. In some situations, it is more appropriate to expect the precise learning and recall associated with fill-in-the-blank and MDT multi-digit questions than it is to reward the good test takers who are able to attain reasonable scores because their "selection" abilities with the five-choice method raised their rank in class.

8.1.3 Matching: A variety of techniques are associated with matching. To a limited degree, the multiple choice method is based on matching; each of the five alternatives is either the correct choice or an incorrect one. Matching tests tend to be a variation of multiple choice techniques with ten to twenty-five alternative responses. More than twenty-five foils (alternatives) have not been considered a viable test form because the students would need too much time to read the choices. Also, the standard practice is to "mix up" the alternatives, that is, avoid any inherent order to the selection. The MDT long-list method has reversed both of those standard practices. First, the lists should be very long, well beyond the twenty-five choice limit. Furthermore, **there must be some order to the alternatives.** Usually the order is alphabetical.

In this light, the MDT long-list test format can be considered a "**super matching**" method. Or should it be "**super multiple choice**"? A better description is "**machine-scored fill-in-the-blank**".

8.1.4 Fill-In-The-Blank, Completion and Short Answer Methods: There is ambiguity in the use of names for these test methods. Fill-in-the-blank questions can literally have a blank space for a discrete word (or two to three words) in the sentence. A discrete and very brief response is the key characteristic, not the actual blank space. Fill-in-the-blank questions could have only a stem phrase, as in multiple choice or matching questions, but with an open end instead of a selection of foils. For example: The husband of Queen Victoria was (______). This format is often called "completion" testing. If the answer is brief and discrete, completion is the same as fill-in-the-blank. However, a completion answer sometimes could be a lengthy phrase not suitable for a long list of discrete terms nor similar to fill-in-the-blank.

Sometimes the questions are complete statements, like "What nationality was Prince Albert?" A short, discrete answer is possible. It functions like a fill-in-the-blank question and could be rewritten as such. Duchastel (1981a and 1982b) and others refer to such statements as "short answer" questions. Another "short answer" question could be "Who was Prince Albert?" A short answer could be "He was the German-born, first cousin and husband of Queen Victoria." Clearly, this is a different type of response, and really a different kind of question. Likewise, the exact same question could require several paragraphs or even pages for an essay answer. How short is short? Teachers need to specify their expectations, and the label "short answer question" is not precise. This author and the MDT Educational System refer to "short answer" questions as junior versions of essay questions. We also adapt the term "discrete answer" questions to encompass fill-in-the-blank and closely related question formats.

In these testing method there are no hints or alternative answers. This is called "free response." The student must think of the answer; recall is required. The entire memory of the student is put to use, but the mind automatically eliminates the unrelated knowledge. If the single correct response is known, the selection of an answer is over. Often two or more options are in the student's mind, but eventually some decision, right or wrong, is made. If left blank, it is the same as a wrong answer.

In contrast, the only difference between the fill-in-the-blank and the MDT discrete answer method is the long list. Intentionally too long to be read through, lists even include "999-No reasonable answer is on this list." The lists, however, are suggestive. If the student knows the answer starts with a certain letter, there is a segment of the list which can be read. Also, in the final minutes of a test, some students might hunt through the list for a term they could recognize, even though they might not independently recall it. Although this factor is uncontrolled, it does not appear to be a major draw back. And if it is, then the MDT four-digit version with ten thousand terms could rectify this limitation. The MDT answer bank method is both "free response", "discrete response" and machine scored. The MDT multi-digit testing method closely approximates fill-in-the-blank tests, but with the advantage of machine scoring.

8.2 Previous Attempts To Improve Multiple Choice Situations

A variety of alternative techniques have been developed by various instructors. They all attempt to solve the same problem of obtaining machine scoring beyond the multiple choice limitations.

8.2.1 Large Matching Methods: Some professors have made large matching tests with listings of perhaps twenty alternatives. For every five alternatives, the responses of A-E (five choices) are repeated. In other words, the first, sixth, eleventh and sixteenth answers would all be encoded by the letter A.

A slightly improved version is to use the ten-choice answer sheets, with the numbers 0-9 (or 1-10) being repeated in sequential order on the list of responses. Walter Vernon of the Psychology Department at Illinois State University used such a system for a number of semesters as an alternative to the regular multiple choice arrangement. However, he encountered some limitations. There was still a one in ten chance of guessing the answer correctly if absolutely no answer was known. In addition, because the lists seldom exceeded one hundred terms, there was a temptation for the students to read through the entire listing, essentially converting it into a form of multiple choice hunt to recognize any reasonable answers. Often only two to four reasonable alternatives would be on a one hundred term list used for twenty to forty questions.

Vernon used the term "long list" in describing his particular variation of computer-scored testing. When he became aware of the work by Anderson (the systems were developed independently) he provided some interesting comments:

1. In a course which does not use a specific textbook, it is possible that subject terminology will not be as precise because the students could be reading from several books where the terms are different. This is a minor problem in physical sciences and industrial technology fields. However, it can be a major problem in social sciences.
2. With large numbers of students taking the same course from him in different semesters, Vernon once had an experimental group using a long-list method. Unannounced, he switched a test to the multiple choice mode. In comparison with the students from the previous year which had not been studying for a long-list test, the experimental group had eleven percent fewer errors on the unannounced test.

It should be noted Vernon's classes had structured learning materials with study questions. He observed the harder the study questions, the better the exam grade became. However, the provision to students of answer keys to the structured materials resulted in lower grades because students relied on them too heavily.

Variations of this method of long-list testing have been used by Walter Vernon off and on for fifteen years. Sometimes he stops using it because of negative feedback from the students. This is apparently for the same reasons that some students dislike the MDT answer bank method; specifically, it is more rigorous and requires a greater amount of learning. However, the rigor (difficulty) and methods of testing should be at the discretion of the individual professor (or the school administration and school board) who sets the level of expectations for the students in a class. Nevertheless, in an era of evaluations of instructors by their students, negative feedback from students can be detrimental to an instructor's security and promotion unless the administration is supportive of increased rigor in testing. It is not necessarily fair to treat every student in the class as if they were going to be a specialist or a "major" in the particular discipline. However, at least some pupils will want to be specialists in a field and should thus be expected to have a full mastery of their subject matter. The issue of mastery learning is discussed in Section 9.2.

8.2.2 Keylist: Research by William Ward (1982) of Educational Testing Service (ETS) described the closest method yet found to the MDT long-list answer bank technique. "The 'keylist' format required the examinee to think of an [answer], to locate this word in a ninety item alphabetized list, and to record its number on the answer sheet. This latter format was included as a machine-scorable surrogate for a truly free-response test."

Anderson was unaware of the work by Ward until after the prototype MDT software was in use. This was fortunate. Ward's research showed no educational advantage from free-response methods (discussed further in Section 8.3). Furthermore, the impression given is that development of such a method had already been accomplished. To the contrary, Ward's "keylist" method was limited in the following ways:

a. Only ninety terms were in a two-digit list. With fifteen minutes to answer twenty question, the students had time to quickly read through all of the choices if they desired.

b. The research data was scored manually. The article does not state how the keylist questions were scored. In a telephone conversation, Ward clarified that no software programming of scanners or computers was done. For his research purposes, manual scoring was adequate and cost effective.

c. The potential for computer-assisted improved feedback utilizing the terms on the lists was not perceived in the keylist research because the tests were not machine scored. When Anderson devised the MDT answer bank method (see Chapter 2), the use of the encoded terms in the computer memory was an afterthought, not a primary reason to develop the system.

Without a computer program and in light of the research results, Ward and his associates at ETS did not pursue further development or evaluation of the keylist method.

8.2.3 The Alphabet Method: Another variation of encoding long lists is to utilize the letters of the alphabet for the selection of the alternative choices. Without repeating any letters, twenty-six distinct codes are available using the letters A-Z. The letters can be repeated twice for lists of up to fifty-two answers or even repeated four times to give one hundred four possible responses. The likelihood of guessing a correct answer is, therefore, reduced to one chance out of twenty-six. However, the computer is unable to retain in memory and distinguish the word answers for more than one set of twenty-six alternatives. An additional disadvantage of the alphabet method is that relatively few questions can be accommodated on each answer sheet since each question requires twenty-six cells available for marking the one correct answer. In contrast, the three-digit MDT format uses thirty cells for up to 999 alternative answers.

8.2.4 "Combined Response Areas Per Question" Method: In another attempt to utilize traditional multiple choice answer sheets, up to five response areas (for example, questions 11, 12, 13, 14, 15) were assigned for each single question. Each response area has five choices from A-E. With this method there are essentially twenty-five discrete answer spaces available and the student should make only one mark in one cell of those five response areas. The possible answers are in a list encoded as 11-A, 11-B, etc., to 15-D and 15-E. This system can function, but it is an inefficient use of the space on the answer forms. In addition, there is a certain amount of confusion for the student because four out of five of the response areas would be left blank.

8.2.5 Letters and Numbers: One of the standardized tests for architecture certification (Balen, 1984) uses a long matching technique in which each of forty to eighty responses has a letter and number code. Examples are A1, A2, . . . A9, B1, B2, . . . B9, to E9. With ten letters and ten numbers, there is a maximum of one hundred responses. However, the responses are grouped. For example, the few numerical responses are all listed together, reverting back toward the characteristics of regular multiple choice tests.

8.2.6 Other Methods and Summary: There are probably several other methods in existence. Any sample tests or contact addresses would be appreciated. Also, the MDT Corporation has designs for some distinctive methods not seen in the literature reviewed. When available, they will be announced in the MDT Bulletin.

All of these various methods have confronted the same problem: how to have more than five or ten choices for certain types of test questions. All the alternative methods have three similarities.

a) Use of a greater number of cells on an answer form;
b) Generation of a longer list of alternative responses; and
c) Development independent of the work by others.

Of all of the methods known to the author thus far, the MDT answer bank method is by far the easiest to implement. It is applicable in all of the situations for which other educators have developed the above mentioned techniques. It should be noted that the MDT answer bank method is the first and only to have

a) significantly more than one hundred terms and
b) improved feedback of word responses with each coded answer.

8.3 Previous Comparative Research

Student comments and deductive reasoning suggest that the MDT multi-digit method of testing should result in some advantages in cognitive achievement when compared with the standard five-choice method. The advantages should be similar to those of the fill-in-the-blank format. The published literature encountered thus far is supportive but less than conclusive on the topic.

8.3.1 Test Formats for Standardized Tests: An important study by William Ward (1982) explored "the effects of an open-ended format with item types like those used in conventional examinations", specifically sentence completion, analogies and antonyms involving one or two-word answers. Each of these three item types was examined using four formats. Mulitple-choice is the standard select-from-five format as used in standardized tests such as the SAT, ACT, and GRE. The "keylist" format approximates the MDT use of long-lists or answer banks (see Section 8.2.2). Manually scored written responses are used in two formats for single-answer and multiple-answer tests. Fifteen to twenty questions for each item type in each format were asked to 315 university students. Ward concludes (abstract, p. 1): ". . . discrete verbal item types appear to measure essentially the same abilities regardless of the format in which the test is administered."

A review of the published tables, however, rasies a few questions. First, the "test difficulty" statistics reveal mean scores for the multiple-choice tests to be substantially lower (approximately four out of twenty points, without the standard correction for guessing) than the "keylist" mean, and with standard deviations higher by about one point. This is exactly the opposite of what would be expected and of what has been experienced for four years with the MDT multi-digit method. The possible explanations include: a) easier keylist questions, b) multiple fully correct answers on the keylist, c) presence of and credit for partially correct "marginally appropriate" answers on the keylist (p. 3), d) inappropriately selected "foils" for the remainder of the keylist, e) all of the above in combination. Whatever the reason, this reversal of difficulty needs to be clarified if the keylist research is to be fully relevant to the MDT answer bank method.

Second, the differences in the test reliabilities (coefficient alpha) associate with the response formats are reported by the medians (range .68 to .75) with "no differences" (p. 4) rather than by the means (range .61 to .71). By either measure, multiple-choice is lowest. Also, when compared according to each of the three item types separately, the multiple-choice reliability is always lowest of the four formats except in one case (keylist is .06 lower than multiple-choice for sentence completion). With the analogies questions, the range is from .70 for keylist down to .45 for multiple-choice, the least reliable of all twelve combinations of item types and formats. Ward ignores the trends when he writes (p. 4): "The differences apparently represent somewhat less success in creating good analogies items rather than any differences inherent in the open-ended response formats". Instead, an alternative interpretation of the data could be that the difficulty in creating good analogies items apparently is greater for multiple choice than for open-ended response formats. In other words, the cited data appears to call for additional research rather than conclusions that format is inconsequential.

Third, the research is for a static condition. The 315 university students in the sample did not prepare for tests under the different formats. The results might be applicable to standardized aptitude tests as a summative measure, as was Ward's purpose. However, the methodology does not address the question of if and how each testing method can serve a formative function to enhance learning. Each specific test format used during a semester or over many years could be the "treatment" needed to stimulate student learning. The best one (or several) should be incorporated into the summative standardized tests. With related study materials and guidance from teachers, students would be prepared appropriately, and the educational process would benefit. Although arguable that this could be a case of "tests driving the curriculum", such is already the reality with the present limited variety of multiple-choice questions on standardized tests. The argument is that greater format variety may encourage better learning.

The issue of test format to stimulate the learning process is not addressed by Ward's research. Therefore, his conclusion of sameness between formats is not relevant to issues of tests as formative tools. The pedagogical use of discrete answer free-response questions makes this issue especially important now that the MDT innovation offers the time and cost advantages of machine-scoring for such questions.

8.3.2 Test Formats as Research "Treatments" for Retention of Learning: Research on the effect of the examination format on memory has attracted attention for many decades. In these studies the research methodology uses different test formats as "treatments". The researcher then examines the influence, if any, of each format. In 1934 George Meyer published the findings from his doctoral dissertation on four testing formats: true/false, multiple-choice, completion and essay. Tests were given on the day after three study periods and again after five weeks. The eleven summary results (pp. 660-661) clearly indicate the superiority of recall [completion] tests over recognition [true/false and multiple choice] formats. Interestingly, the Meyer research is not cited in any of the other comparative studies encountered. It merits consideration in future studies on this topic.

Sax and Collet (1968) summarize relevant comments from eleven studies. A lack of consensus on the educational effects of multiple-choice and recall examinations is indicated. Their own research results favored the multiple-choice method, but the limitations of their methodology were pointed out by Lorraine Gay.

Gay's research (1980) found that a "treatment" of completion-style tests during a university course yielded twenty percent greater retention than did a treatment with multiple-choice tests when retention was measured with a completion-style post-test. However, no difference was found when a multiple-choice post-test was used, possibly because a "practice effect" counteracted any "learning effect" advantage of the completion-style treatment. Gay's final comments (p. 50) bear repeating: "The results of this study indicate that testing mode may also [like instructional method] have a significant effect on retention. The potential importance of this finding, coupled with the preplexing findings of the Sax and Collet (1968) study, point to the need for further investigations in this area."

8.3.3 Test Format for Consolidation of Learning: Some of the most recent and most interesting research has been reported in the nine publications by Philippe Duchastel (three with co-author Ronald Nungester) between 1979 and 1984. His principal thesis is that testing immediately after learning serves to "consolidate" learning, with the result of greater and longer retention of the information (1983). Student respondents in the research read a short passage and then have one of four treatment tests or a filler activity. Two weeks later (and in one case five months later (1981a)), they are retested. The results consistently show greater retention, with retest scores being up to double the number of correct answers for the previously tested ["treated"] students versus those previously not tested. "Testing may thus be a powerful way of enhancing long term retention" (1981a, p. 470). "In summary, research on the testing effect suggests that all instruction, including the teaching of abstract ideas, should conclude with a brief test, the purpose of which is not primarily to assess learning but to consolidate it. This is a suggestion which is eminently practical, in the sense that it can be relatively easy to implement (since no grading need be involved) and it can be instituted in short order. An essential requirement however is a realization on the part of educators that testing is not solely a means of assessment, but also a means of assisting learning" (1983, p. 211).

Included in his work on whether or not to test promptly, Duchastel also examined the effect of different test formats, including multiple-choice, non-cued free recall, and cued discrete answer fill-in-the-blank/completion style (called short answer by Duchastel, see Section 8.1). The discrete answer format was clearly superior in the 1981 article. "The presumed reason for this is that the retrieval from memory of appropriate answers in response to [discrete answer questions in the treatment test] involves deeper memory search than does the identification of appropriate alternatives in answering multiple-choice questions" (1981, p. 224). The deeper memory search appears to consolidate better learning.

However, in 1982b Duchastel strives to control the influence of "practice effect", that is the effect of taking the retest in the same format as the earlier test. Three random groups were formed from 135 high school students. Although both treatment groups did substantially better by up to double the retest scores of the control group, the comparative results on test formats were quite unexpected. The multiple-choice group outperformed [7.7 versus 6.7 points] the discrete answer group on the twelve multiple-choice retest items. Moreover, on the twelve discrete answer retest items, the scores of the discrete answer group were only 0.4 points higher (not statistically significant) than the multiple-choice group. "The superiority of the short-answer [fill-in-the-blank] test in the previous study (Duchastel, 1981) may have been due in some part to a practice effect. The issue remains far from settled however, since the strength of each factor, consolidation and practice, cannot be quantitatively determined. Further research using refined procedures is evidently warranted. Indeed, the relative superiority of the multiple-choice group over the [discrete-answer group] on multiple-choice retention items could be due either to a greater practice component or to a greater consolidation component" (1982b, p. 312).

"In summary, it appears that the testing effect involves both a consolidation component [treatment tests versus no test] and a practice component [format of treatment test], with the former seemingly playing the more important role . . . [However, the study's] design does not permit a quantitative determination of the magnitude of each factor" (Duchastel 1982b, p. 312).

The implications of the Duchastel research on the MDT innovation are far reaching. Frequency of testing is highly desirable. For the teacher/instructor, that means writing and grading more tests. The MDT method facilitates question writing, grading and feedback to students. Although Duchastel states that grading might not be necessary, such a practice could be (1) unpopular with students and parents, (2) short-lived if students do not perceive the benefits, and (3) overlooking the important benefits of positive feedback offering yet another avenue to improve retention.

The question of which test format is best remains unanswered. Apparently neither format is grossly superior nor inferior. Each has its strengths, but further research is clearly warranted to determine when, where and how each format can be best utilized to enhance student learning.

8.3.4 Comments on Previous Studies: None of this research, nor the research reported in the following sections, aims to discredit any of the testing methods. Each method has and will continue to offer advantages for particular circumstances. It is only when two or more methods can relate to the same specific educational objective, such as recall or application or narrative respsonses, is there any question of which method is better for the given circumstances. Even then, use of a variety is probably better than the use of the single best method. Within the realm of machine-scored testing, the MDT multi-digit testing method definitely enhances variety. It is at least an additional valid technique and, therefore, could merit widespread usage. It may also be the best technique in specific circumstances. The sections that follow report the full extent of the comparative research directly using the MDT techniques as of 1986.

8.4 Research With The MDT Multi-Digit Test

Research by Paul Anderson, Miriam Hill, Shamim Naim and William Walters, Jr. (1985) compared three test methods (including the MDT multi-digit method) on the place name portion of a World Geography course. Their exploratory research used a Latin Square/recurring measures methodology with 188 students during a semester-long comparison. The students were advised as to the test method used for each segment of their course. An unannounced post-test provided the final data. Retention of cognitive learning was highest when students had studied for the fill-in-the-blank method, second with the MDT method and lowest with multiple-choice questions. This was exactly as hypothesized. Although only the fill-in-the-blank method yielded a statistically significant difference (retention approximately eight to ten percent greater than in the other two methods), the results are considered to be conservative because of limitations in the research methodology.

Because of the importance of this initial research, the entire publication by Anderson, Hill, Naim and Walters (1985) is reprinted below by permission of the Illinois Association for Supervision and Curriculum Development.

8.5

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COMPARISON OF COGNITIVE RETENTION FROM THREE TESTING METHODS: FILL-IN-THE-BLANK, MULTIPLE CHOICE AND MULTI-DIGIT TEST (MDT)

by
Paul S. Anderson
Miriam H. Hill
Shamim Naim
William D. Walters, Jr.

8.5.1 Introduction

To assess student learning of factual information, especially in introductory courses with large enrollments, instructors frequently turn to fill-in-the-blank or five-answer multiple choice tests. Both of these have well known limitations and advantages. Duchastel (1981) and Duchastel and Nungester (1982) indicate that the efficacy of recall and consolidation/retrieval of the short answer (fill-in-the-blank) test is greater than that of the recognition/discrimination pattern of the multiple choice test. However, computer scoring for the multiple choice test is an important factor.

Another option, the Multi-Digit Test (MDT), is now available with a variety of unique features. In a Multi-Digit Test the students are given lists of up to one thousand alphabetized potential answers (Figure 1). The lists are intentionally too long to be easily scanned for recognition. When the student reads the question, the answer should come to mind by recall. He or she then goes to the appropriate alphabetical list where each answer has a three digit numerical code. For example, What city is the capital of Thailand? Answer: Bangkok. Code number: 781. The selected code is marked on a special machine-scored answer sheet (Figures 2a and 2b). The process of recording an answer is slightly slower than in conventional five-answer tests, but the possibility of guesswork is almost eliminated. Much of the same thought process required in the fill-in-the-

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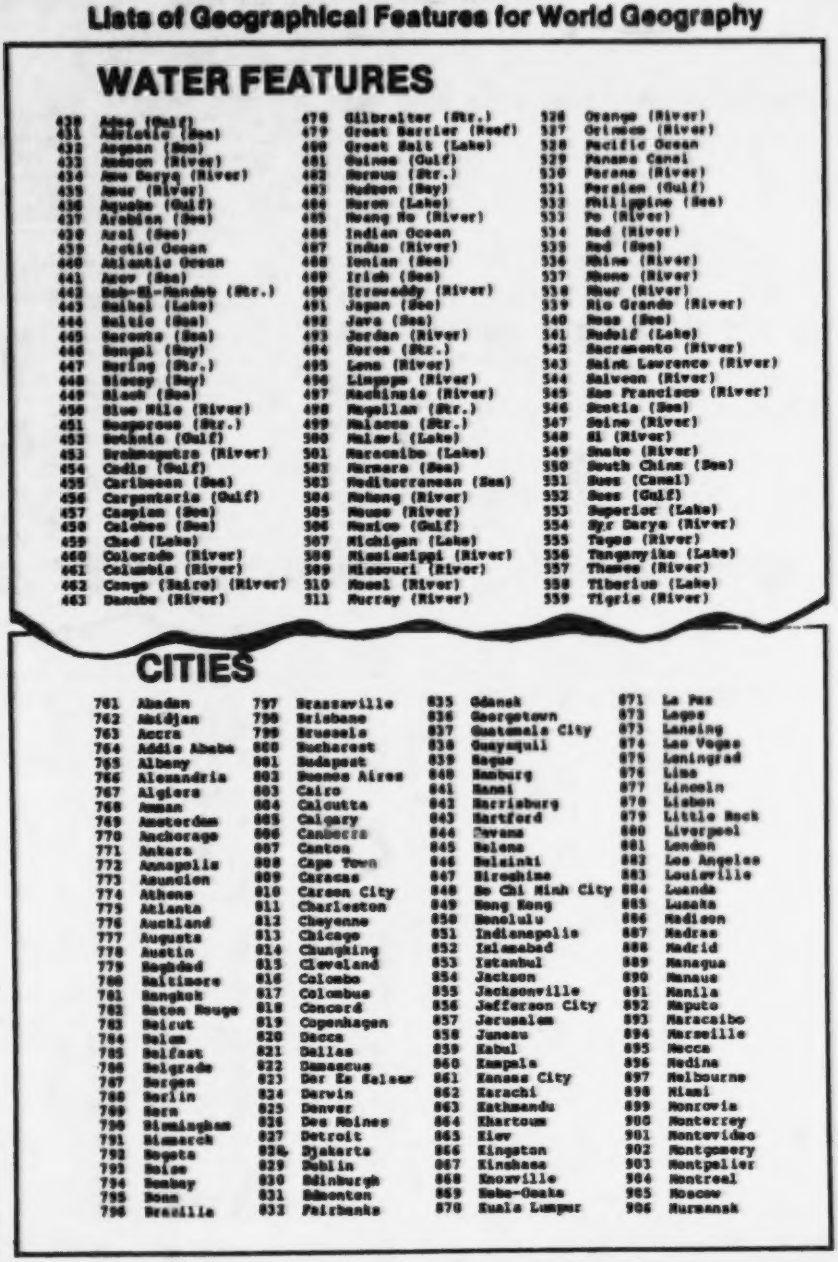
PAUL S. ANDERSON is Associate Professor of Geography, SHAMIM NAIM is Assistant Professor of Geography and WILLIAM D. WALTERS JR. is Associate Professor of Geography in the Department of Geography-Geology at Illinois State University, Normal, Illinois. MIRIAM H. HILL is Assistant Professor of Geography in the Department of Geography at Indiana University Southeast, New Albany, Indiana.

Figure 8-1 Part of a "Long List": Lists of Geographical Features of World Geography



Lists of Geographical Features for World Geography

WATER FEATURES

430	Aden (Gulf)
431	Adriatic (Sea)
432	Aegean (Sea)
433	Amazon (River)
434	Amu Darya (River)
435	Amur (River)
436	Aqaba (Gulf)
437	Arabian (Sea)
438	Aral (Sea)
439	Arctic Ocean
440	Atlantic Ocean
441	Azov (Sea)
442	Bab-El-Mandeb (Str.)
443	Baikal (Lake)
444	Baltic (Sea)
445	Barents (Sea)
446	Bengal (Bay)
447	Bering (Str.)
448	Biscay (Bay)
449	Black (Sea)
450	Blue Nile (River)
451	Bosporous (Str.)
452	Bothnia (Gulf)
453	Brahmaputra (River)
454	Cadiz (Gulf)
455	Caribbean (Sea)
456	Carpentaria (Gulf)
457	Caspian (Sea)
458	Celebes (Sea)
459	Chad (Lake)
460	Colorado (River)
461	Columbia (River)
462	Congo (Zaire) (River)
463	Danube (River)
478	Gilbraltar (Str.)
479	Great Barrier (Reef)
480	Great Salt (Lake)
481	Guinea (Gulf)
482	Hormuz (Str.)
483	Hudson (Bay)
484	Huron (Lake)
485	Huang He (River)
486	Indian Ocean
487	Indus (River)
488	Ionian (Sea)
489	Irish (Sea)
490	Irrawaddy (River)
491	Japan (Sea)
492	Java (Sea)
493	Jordan (River)
494	Korea (Str.)
495	Lena (River)
496	Limpopo (River)
497	Mackinzie (River)
498	Magellan (Str.)
499	Malacca (Str.)
500	Malawi (Lake)
501	Maracaibo (Lake)
502	Marmara (Sea)
503	Mediterranean (Sea)
504	Mekong (River)
505	Meuse (River)
506	Mexico (Gulf)
507	Michigan (Lake)
508	Mississippi (River)
509	Missouri (River)
510	Mosel (River)
511	Murray (River)
526	Orange (River)
527	Orinoco (River)
528	Pacific Ocean
529	Panama Canal
530	Parana (River)
531	Persian (Gulf)
532	Philippine (Sea)
533	Po (River)
534	Red (River)
535	Red (Sea)
536	Rhine (River)
537	Rhone (River)
538	Ruhr (River)
539	Rio Grande (River)
540	Ross (Sea)
541	Rudolf (Lake)
542	Sacramento (River)
543	Saint Lawrence (River)
544	Salween (River)
545	Sao Francisco (River)
546	Scotia (Sea)
547	Seine (River)
548	Si (River)
549	Snake (River)
550	South China (Sea)
551	Suez (Canal)
552	Suez (Gulf)
553	Superior (Lake)
554	Syr Darya (River)
555	Tagus (River)
556	Tanganyika (Lake)
557	Thames (River)
558	Tiberius (Lake)
559	Tigris (River)

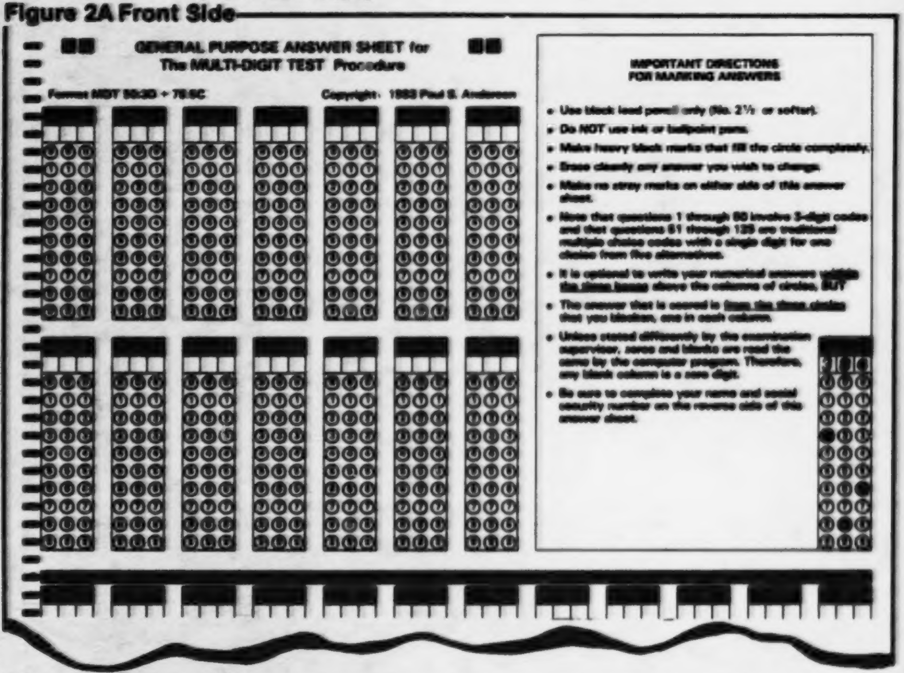
CITIES

761	Abadan
762	Abidjan
763	Accra
764	Addis Ababa
765	Albany
766	Alexandria
767	Algiers
768	Amman
769	Amsterdam
770	Anchorage
771	Ankara
772	Annapolis
773	Asuncion
774	Athens
775	Atlanta
776	Auckland
777	Augusta
778	Austin
779	Baghdad
780	Baltimore
781	Bangkok
782	Baton Rouge
783	Beirut
784	Belem
785	Belfast
786	Belgrade
787	Bergen
788	Berlin
789	Bern
790	Birmingham
791	Bismarck
792	Bogota
793	Boise
794	Bombay
795	Bonn
796	Brasilia
797	Brazzaville
798	Brisbane
799	Brussels
800	Bucharest
801	Budapest
802	Buenos Aires
803	Cairo
804	Calcutta
805	Calgary
806	Canberra
807	Canton
808	Cape Town
809	Caracas
810	Carson City
811	Charleston
812	Cheyenne
813	Chicago
814	Chungking
815	Cleveland
816	Colombo
817	Columbus
818	Concord
819	Copenhagen
820	Dacca
821	Dallas
822	Damascus
823	Dar Es Salaam
824	Darwin
825	Denver
826	Des Moines
827	Detroit
828	Djakarta
829	Dublin
830	Edinburgh
831	Edmonton
832	Fairbanks
835	Gdansk
836	Georgetown
837	Guatemala City
838	Guayaquil
839	Hague
840	Hamburg
841	Hanoi
842	Harrisburg
843	Hartford
844	Havana
845	Helena
846	Helsinki
847	Hiroshima
848	Ho Chi Minh City
849	Hong Kong
850	Honolulu
851	Indianapolis
852	Islamabad
853	Istanbul
854	Jackson
855	Jacksonville
856	Jefferson City
857	Jerusalem
858	Juneau
859	Kabul
860	Kampala
861	Kansas City
862	Karachi
863	Kathmandu
864	Khartoum
865	Kiev
866	Kingston
867	Kinshasa
868	Knoxville
869	Kobe-Osaka
870	Kuala Lumpur
871	La Paz
872	Lagos
873	Lansing
874	Las Vegas
875	Leningrad
876	Lima
877	Lincoln
878	Lisbon
879	Little Rock
880	Liverpool
881	London
882	Los Angeles
883	Louisville
884	Luanda
885	Lusaka
886	Madison
887	Madras
888	Madrid
889	Managua
890	Manaus
891	Manila
892	Maputo
893	Maracaibo
894	Marseille
895	Mecca
896	Medina
897	Melbourne
898	Miami
899	Monrovia
900	Monterrey
901	Montevideo
902	Montgomery
903	Montpelier
904	Montreal
905	Moscow
906	Murmansk

BEST COPY AVAILABLE

Figure 8-2 An Answer Sheet for the Multi-Digit Test (Reduced size)

Figure 2A Front Side



GENERAL PURPOSE ANSWER SHEET for
The MULTI-DIGIT TEST Procedure

Format MDT 50:3D + 75:5C

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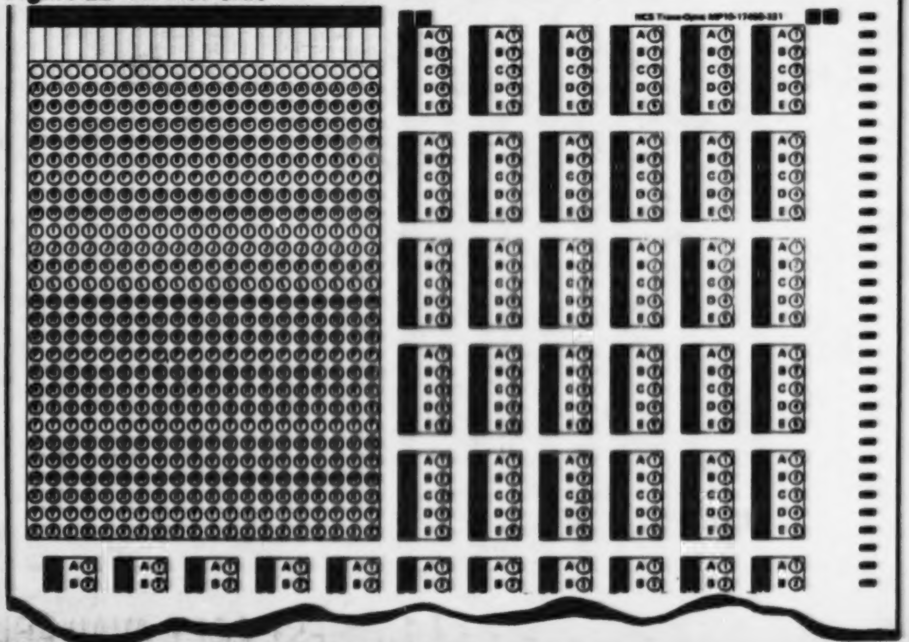
IMPORTANT DIRECTIONS
FOR MARKING ANSWERS

- Use black lead pencil only (No. 2½ or softer).
- Do NOT use ink or ballpoint pens.
- Make heavy black marks that fill the circle completely.
- Erase cleanly any answer you wish to change.
- Make no stray marks on either side of this answer sheet.
- Note that questions 1 through 50 involve 3-digit codes and that questions 51 through 125 are traditional multiple choice codes with a single digit for one choice from five alternatives.
- It is optional to write your numerical answers within the three boxes above the columns of circles, BUT
- The answer that is scored is from the three circles that you blacken, one in each column.
- Unless stated differently by the examination supervisor, zeros and blanks are read the same by the computer program. Therefore, any blank column is a zero digit.
- Be sure to complete your name and social security number on the reverse side of this answer sheet.

Figure 2B Reverse Side



blank test is present in the MDT method. This suggests advantages of MDT over traditional multiple choice testing while also having the advantages of computer scoring not available in fill-in-the-blank tests. The advantages, applications and availability of the Multi-Digit Test are discussed by Anderson (1984).

8.5.2 Method

During the Spring of 1984, preliminary research was conducted to assess the impact of the Multi-Digit Test. The hypothesis examined was that improved student learning and retention of information will result when students study for Multi-Digit tests in comparison with traditional five-alternative multiple choice tests. Comparisons were also made with fill-in-the-blank tests. The study was structured as preliminary and exploratory research; it was not possible to obtain ideal controls in the research context. Therefore, at various stages during the research, it was necessary to make assumptions concerning the sample and the methodology. These assumptions are noted in the pages that follow.

The sample was comprised of 188 students who completed all of the testing and data requirements in a Freshman-level University Studies (breadth requirement) course called World Geography. Those students were in five sections of that course under the instruction of four professors. One professor had a double section which was treated as one of the three groups. Another professor had two sections; one each of her sections was joined with the single sections from the other two professors, thereby forming the second and third groups. The student enrollment in each section was at the discretion of the students and no attempt was made at randomizing or attempting to otherwise balance the three groups. Likewise, it was not possible to have four professors give identical lectures even though one textbook was used in all of the sections. The characteristics of the three groups were monitored throughout the semester with a pre-test, with identical questions in the non-research parts of the examinations, and with the main research data. All evidence indicated that the three groups were basically similar in academic ability.

Although the course, World Geography, deals with much more complex material, the research data were limited to one part of the course, the learning of selected geographical place names in relation to maps and key issues in the textbook. The content of that aspect of the course was standardized through the preparation of lists of geographical features for each of the continental areas that were discussed in turn during the semester. Each of the four professors distributed the printed lists and a selection of outline maps to the students at the beginning of the appropriate classes. Students were asked to learn those geographical features, twenty of which would be covered in the next test during the semester, excluding the final examination. Some of those places might be mentioned during the subsequent lectures, but no professor made an explicit attempt to go through the list nor to drill those locations with their students. The conceptual and analytical aspects of the course were evaluated separately by each professor and were not included in the research data.

The mode of testing about the place names was rotated among the three groups in each of three tests during the semester. This made possible a Latin square/repeated measures methodology which helps minimize the influence of any differences between classes and between professors (see the arrangement of the shaded cells in Figure 3a). As expected, the three methods of answering identical questions were not equal in difficulty. For example, on the first test, students with the fill-in-the-blank questions had an average of 65% correct, while the MDT group averaged 67.6% and the five-choice group averaged 78% on the exact same questions. This was as hypothesized, but the trend did not continue. On the second test, the fill-in-the-blank group averaged 68% correct, the Multi-Digit students averaged 57.6% and the five-choice was again the highest at 75.7%. Results on the third rotation were similar to those on the second: 76.6%, 69.5%, and 84.8% respectively. The MDT method was almost as hard or harder than the fill-in-the-blank questions, probably in part because the students lacked experience with MDT in spite of efforts to explain it well in advance of the test dates. The five-choice tests were consistantly the easiest.

8.5.3 Post-test Evaluation of Retention

In the final week of classes, sixteen additional 5-choice questions were asked over the place name content. This post-test was unannounced and not used in assigning student grades. It was used to determine if the testing method for which the students studied on earlier examinations influenced their retention of learning. In other words, would a student who was required to learn the location of Laos well enough to respond to a fill-in-the-blank question, do better when asked to locate Laos in a later surprise question than a student who only had to learn that country's location well enough to pick it out of five possibilities? Furthermore, how did those who studied the place name locations for the MDT tests compare with the other two groups?

Analyses of the post-test were done on the grouped data tallies for each question and also by the Latin square method. The grouped tallies are presented in Figure 3a. As indicated in line 20, there was minimal difference between the three groups. Groups 2 and 3 were virtually the same, whereas Group 1 had marginally higher scores, as was also indicated on other testing aspects of the course, such as in lines 21 and 22, referring to the material from the fourth segment of the course.

When the mean percentages of correct answers are compared across each of the fourteen rows (rows 2-5, 7-11 and 13-17), the impact of the three testing methods on student retention is revealed (summarized in Figure 3b). In nine of the fourteen questions, the group that had studied for the five-choice test method had the lowest mean percentage of correct answers in the pre-test. Eight times the highest percentage was with the students who had studied for the fill-in-the-blank method. In between these two methods, precisely as hypothesized, were the cases in which the students had studied for the Multi-Digit Test. The major difference in the average of the means (4.0%) occurs between the fill-in-the-blank and the Multi-Digit Test, with a smaller difference (1.4%) between the Multi-

Figure 8-3 Tables of Calculated Means by Questions

Figure 3a: Table of Means for Post Test Questions

Line 1	Col. A	B Quest. No.	C Answer	D G1=W+H2	E G2=A+H3	F G3=N+N	G MEANS
				F-B	MDT	5-C	
2		51	Ozarks	83.6	82.1	72.7	79.3
3	TEST	52	Sask.	40.0	28.4	36.4	34.6
4	1	53	New Hamp.	70.9	65.7	51.5	62.2
5		66	Ottawa	45.5	34.3	48.5	42.0
6	Sub 1			60.0	52.6	52.3	54.7
				MDT	5-C	F-B	
7		55	Baltic	61.8	64.2	57.6	61.2
8	TEST	56	Seine	50.9	41.8	50.0	47.3
9	2	57	Sicily	74.5	71.6	74.2	73.4
10		58	Volga	30.9	40.3	53.0	42.0
11		59	Vladiv.	69.1	59.7	63.6	63.8
12	Sub 2			57.5	55.5	59.7	57.6
				5-C	F-B	MDT	
13		60	G. Oman	70.9	59.7	59.1	62.8
14	TEST	61	Bangkok	65.5	73.1	69.7	69.7
15	3	62	Tehran	69.1	83.6	71.2	75.0
16		63	Indus	45.5	56.7	56.1	53.2
17		64	Ghats	43.6	50.7	47.0	47.3
18	Sub 3			58.9	64.8	60.6	61.6
19							
20	Total 1+2+3			58.8	57.6	57.5	57.9
21	TEST	54	Bolivia	60.0	58.2	59.1	
22	4	65	Madag.	87.3	73.1	74.2	

Figure 3b: Frequency Table of Order of Means on Fourteen Questions

		High	Middle	Low	Average mean	Differences in average means	
line 25	Five-Choice	3	2	9	55.8	1.4	5.4
line 26	Multi-Digit	3	7	4	57.2	4.0	
line 27	Fill-in-Blank	8	5	1	61.2		

n = 14

Figure 8-4 Tables of Means in the Latin Square Analysis

Figure 4a: Table of Mean Values in the Latin Square

GROUP	G1 W + H2	G2 A + H3	G3 N + N	Means by Order of Tests
SAMPLE (total = 188)	55	67	66	
ORDER 1 1st Test (Macro + Anglo Am.)	Fill in Blank 60.0	■	▨ 5-Choice 52.3	54.7
ORDER 2 2nd Test (Europe, USSR, J, Aust.)	■	▨ 5-Choice 55.5	Fill in Blank 59.7	57.6
ORDER 3 3rd Test (China, India, Mideast, SEA)	▨ 5-Choice 58.9	Fill in Blank 64.8	■	61.6
Means by Group of Subjects	58.8	57.6	57.5	57.9

Figure 4b: Table of Means for the Three Test Treatments for the Latin Square

Sample	Means for Treatments		
	Fill in Blank	Multi-Digit	5-Choice
Total = 188	61.6	56.8	55.4
A = 165	61.2	56.3	57.2
B = 165	62.4	56.5	56.0

Digit Test and the five-choice method. This is attributed in part to the students' lack of familiarity with the MDT method. When students have more than one exposure to the Multi-Digit Test method, it is expected that MDT would raise its percentages of correct answers, become more similar to the fill-in-the-blank scores, and have a greater positive difference over the five-choice testing method.

8.5.4 Latin Square/Repeated Measures Analyses[1]

The test for statistical significance of the observed difference was the Latin square/repeated measures form of Analysis of Variance. It is based on each individual's responses (188 x 14 = 2632) instead of the grouped tallies. The students in each of the three Groups were tested once on each of the three test dates (Order) and with each of the three testing methods (Treatment). The overall occurrence of Treatment with Group and Order conditions was balanced in such a way that, subject to certain assumptions, the effect of the Treatment alone on the test scores might be assessed. Figure 4a shows the experimental design plus the cell and marginal mean scores from the full sample of 188 students.

Four assumptions are required for the strict appropriateness of this design: (1) The Groups are assumed to be random sub-samples from a common population. Although it was not possible to randomly assign students to classes, there were no apparent substantive differences between the Groups in the pre-test scores nor in any of the supplemental measures. (2) There should be no non-linear Order effects across the Treatment and Group conditions. The right-hand column in Figure 4a shows that the average effect of Order is nearly linear from test to test (2.9% between tests 1 and 2, and 3.0% between tests 2 and 3). This rise in average scores is as expected because the earlier tests were further removed timewise from the post-test date. In other words, retention diminished as time increased. (3) In a repeated measures design, all pairs measures on the same subjects should have constant correlation. This assumption could not be evaluated because of high computer costs. (4) In order for the main effects of the factors to be interpretable without confounding, all pairwise interactions should be negligible relative to the main effects. The triple interaction of the factors is assumed to be negligible throughout. A partial test on the validity of these assumptions is given by the F ratio:

$$^{F}\text{test} = {}^{MS}\text{residual}/{}^{MS}\text{error (within)}$$

Due to the extreme computing requirements of this type of design, it was ultimately found necessary to use the following computational strategy. First, the larger two Groups were pared down to the size of the smallest to meet the requirement of equal sub-samples. This was done by taking two computer generated random samples of 55 from the 66 and 67 member groups. The initial sample population of 3 x 55 subjects is Sample A in Figure 4b. Subsequent analyses revealed a major bias in that Sample A actually reverses the relative magnitudes of means for the MDT and five-choice data. Statistical values have been calculated but are not reported because of this bias. As a check on sampling variability, the entire analysis was run again on a second random sample (Sample B), which preserved the relative magnitudes, but rather weakly and resulting in conservative findings.

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[1] *The majority of the computer programming and statistical analyses was done by Mr. Jon Awbrey.*

It was necessary to use a computational option that did not compute separately the residual error term but pooled it with the last within-subjects error term of the design. This obviated a check of the model assumptions about negligible interactions. Because of limited funds and computer core available, this analysis could only be run on two smaller samples of sixty students (n=3 x 20). In both sub-samples, the hypothesis of negligible interactions was not rejected.

The data were subjected to an Analysis of Variance appropriate to the Latin square/repeated measures design (cf. Winer, (1971)). For Sample B, there was no significant difference between Groups. In fact, great similarity was indicated ($p = 0.973$). The effects of both Order and Treatment were significant at the 0.05 level. Thus the hypothesis of some differences among the Treatment conditions would be supported on the evidence of this sample alone; no evaluation was made of the possible error due to the sampling procecure.

A t-test of estimated contrasts for Sample B was calculated after the influences of Group and Order differences were taken into account. The Treatment contrasts show that there is a statistically significant difference ($p=0.008$) between Treatment 1 (fill-in-the-blank test) and Treatment 3 (five-choice test). Students in academic circumstances such as described in this research retain more knowledge if they studied for a fill-in-the-blank test than for a traditional multiple-choice test with five alternative answers. The final line in Figure 4b indicates that the difference is approximately ten percent of the five-choice mean, even within a few weeks in the same semester of study. The difference (one percent) between the mean scores for the Multi-Digit Test (Treatment 2) and the five-choice test (Treatment 3) was not significant using the conservative Sample B. It cannot be determined whether that difference (approximately three percent) for the entire sample of 188 students is statistically significant.

8.5.5 Conclusion

Although these results are conservative and from exploratory research, they are strengthened because they are almost all in the hypothesized directions indicating that MDT is intermediate between the five-choice and fill-in-the-blank methods. It does seem, therefore, that the Multi-Digit Test may be a mode of educational measurement which stimulates better retention than five-choice tests and also offers the advantages of computerized scoring and analyses. The one concrete conclusion from this research is that more work is merited under rigorously controlled conditions. There is enough promise in these early test results to suggest increased interest in MDT testing.

8.6 Research at University High School

Subsequent research was undertaken by Paul Anderson and Eileen Kanzler during the Fall 1984 and Spring 1985 semesters within the laboratory high school at Illinois State University. The advantages of this laboratory school environment and early research results have been discussed in two papers (Anderson and Kanzler 1985a and 1985b, respectively).

Three of five U.S. History classes in University High School were taught by Kanzler and were utilized in the research. All the students had previously preregistered into classes of about twenty-five students in a semi-random fashion based on class availability, requirements and electives. A pretest and the first two tests of the semester were identical for all three groups in order to ascertain any noteworthy differences between the classes. The mean scores and other descriptive statistics were essentially the same; the class in the second time slot (11:00 a.m.) was arbitrarily designated as the experimental (MDT method) group.

For each of the bi-weekly tests the MDT multi-digit style questions posed to the experimental group were converted to a multiple choice four-foil format for the two control groups. Five to ten multiple choice questions where reasoning or judgment was a factor in the answer were also included on most tests. For the third test (first one with MDT multi-digit questions), no advance notice on the change of format was given to the experimental group. As anticipated, the experimental group achieved a much lower mean score (fifty-two percent) than either of the two control groups (seventy-four percent and seventy-one percent). This is a decline of twenty-eight percent from the average correct scores of the control groups. It was readily apparent to the students that the MDT method based on recall was a much harder, more demanding test. When the same test was subsequently administered in the next class period in a multiple choice four-foil format to the experimental group, the students achieved the same (seventy-two percent) result as the control groups. A few students complained about the difficulty and fairness of the MDT test, not realizing that difficulty is at the discretion of the instructor, who could also have given fill-in-the-blank tests.

Attempts to treat the MDT format of questions as just another (but longer) form of matching test had to be dispelled by enforcing a time limit only slightly longer than the average time needed to complete a multiple choice test of equal length. The students' desire to "search" for the correct answer by random scanning of lists or by process of elimination is apparently a difficult habit to break.

After the first few administrations of the long-list tests, students realized they would have to modify their study habits to accommodate the free-response recall of factual information about U.S. History. Some resisted the testing method and dismissed the material as trivial, insignificant and irrelevant. Course content and objectives, however, are determined by the teacher. Therefore, the criticisms are of education in general and not specifically a result of the MDT multi-digit methodology. Since many students apparently rely heavily on the recognition factor present in multiple choice tests, some objected to the time and effort required by the demands of the recall strategy. Other students claimed the change in study habits was impairing their performance on the multiple choice section where more judgment and reasoning were required. However, an analysis of the multiple choice segment of the final examination revealed that students in the experimental group did as well if not slightly better than the control students.

As the semester continued the experimental group made noticeable gains, at times attaining scores equal to those of the groups with the multiple choice tests. The experimental group's performance on the comprehensive final exam was disappointing (twenty-five percent lower). However, the sheer volume of information was probably a major factor. On one occasion the control groups were given both formats of the test with the MDT format coming first and being unannounced. Their MDT answer bank test results averaged forty-two percent lower than their own multiple choice scores and thirty-seven percent lower than the multi-digit test scores of the experimental group.

8.7 Conclusion

In general, research efforts to date have not shown dramatic improvements in learning and retention that could be attributed to the multi-digit innovation. On the other hand, no evidence nor hypotheses even hint at any detrimental effect when MDT multi-digit or other free-response methods are applied to appropriate subject matter. Clearly, with questions which can be answered with a discrete term or name such as those on the lists, the MDT method is more rigorous, and students respond to this rigor in a desirable way. Although many students indicate their study habits are modified, the qualitative and quantitative aspects of this modification have not been clearly identified. There are sufficient indications of benefits (see Chapters Nine through Eleven) to merit further research.

Chapter Nine

MDT Applications for Mastery Learning and Training

9.1 Introduction

Based on the previous chapter, there is little doubt that the MDT multi-digit method is at least as effective as other machine-scored tests with regard to the levels of cognitive knowledge and application of learning. At present, there is no concrete proof the MDT technique improves retention or other aspects of education. There is also no evidence or even any hypotheses to suggest that the MDT innovation would be less effective than the existing multiple choice technique when questions and testing objectives are the same and are consistent with the objective of testing recall. This present chapter discusses how the MDT method can be utilized in education and training courses which heavily utilize those lower orders of learning. [The higher orders of learning, as in Bloom's taxonomy, are discussed in Chapter Eleven.]

9.2 Mastery Learning, Competency-Based Education And Professional Qualification Examinations

9.2.1 Introduction: Mastery learning is the educational method where a student is required to pass a test at a prespecified level of accuracy before being allowed to proceed to the next segment of the subject matter. If the test score is too low, the student is given additional instruction focusing on the specific subject areas where he/she was unsuccessful on the test.

Competency-based education, or minimum competency testing, dictates that at the end of a course of study, such as the conclusion of high school education, a student is expected to pass an examination at a predetermined minimum level of competency. Failing this, a student is either required to retake specific courses or undergo remedial instruction. Professional qualification examinations use a similar procedure.

9.2.2 The MDT Innovation in University and Professional Examinations: Although the terminology is different, both mastery learning and competency-based education can be applied toward aspects of university level studies and professional qualification tests. For a number of professions, in particular law and accounting, an examination is required to insure that applicants have the minimum required knowledge needed for practicing the profession.

Because of the large number of tests and individuals taking those tests, computer scoring with optical mark scanners is a major component of the testing procedure. The role of MDT multi-digit testing in these situations could be very great.

A society and its citizens have the right to expect reasonably proficient work and services from the employed population. Every area of employment has a certain degree of professionalism. The butcher is expected to cut a pot roast in a specified way. A mechanic should be able to distinguish between a distributor, carburetor and many other parts, or he is not worth his wages. Accountants, lawyers, doctors and people from every well-established profession are expected to know the appropriate professional vocabulary of their fields as well as be able to apply this knowledge in specific circumstances. If a doctor operates on a patient and does not know the differences between various arteries, there is no allowance for him to ask the nurse, "Quick! Give me the five choices from which I can choose!" An incompetent accountant can get you into serious difficulties with the Internal Revenue Service. Consider the case of operators of our large nuclear power plants. There are many things which those people had better KNOW. There are situations in which time is insufficient for searches through the manuals to find the correct response. Soldiers who have not mastered particular weapons systems are a threat to themselves, their fellow soldiers and national security. A heavy equipment mechanic who puts the wrong parts into an engine could cause thousands of dollars of damage. It is unreasonable to expect everything to be done with the books and manuals open in front of the mechanic. If this were the case, there would be no need for the advanced training we give our professionals. Cookbook professionalism is clearly not acceptable, and will never be acceptable. The bottom line is this: **Society expects its citizens to KNOW their areas of specialization.**

Clearly the fill-in-the-blank (discrete answer) testing method would be adequate for many of the testing situations described above. The disadvantage is the slow grading time and high cost. Thus, educators have developed multiple choice questions, some of which will undoubtedly continue to be included in professional certification tests. However, with the availability of the MDT multi-digit testing technique, the near equivalent of fill-in-the-blank questions can now be easily included in required competency testing. Not only can it be included, it should be required. If there is any objection to the MDT discrete answer method because tests would become harder, then the response is this: **Only the people who are able to perform at such levels should be able to charge the professional fees associated with their fields.**

The intent of the MDT method is not to trivialize the learning expectations for professionals in various fields. The existing tests may be kept in their entirety in some instances. On the other hand, computer scored testing with the MDT multi-digit method can now insure that the people are more knowledgeable of their professions and are not merely proficient at recognizing answers out of five alternatives.

9.3 MDT Method In Entrance Level Testing

IQ (Intelligence Quotient) style testing is often used to select the best candidate for specific fields of study. In such cases, carefully prepared, thought provoking multiple choice questions are valuable tools. However, there is also the need for entrance level testing which evaluates the examinee's specific knowledge acquired in earlier stages of learning. The MDT answer bank method offers several advantages in such situations.

In university-level general studies courses, not everyone is a "major" in each of these fields. While this is true, there are some students who will choose to continue in each discipline. The result of this mix of students is that the majors get high grades in the introductory courses but have not truly mastered the vocabulary required in progressively more specialized courses to follow in their career training. A professor could easily utilize the MDT discrete answer method as an entry level test for all students enrolling in a course that has a prerequisite. Preferably, it should be announced while taking their introductory courses. However, a professor could simply inform his class that at the end of the second week there would be a test over the basic vocabulary and definitions which were supposed to have been mastered in the prerequisite course. Anyone failing to satisfy the requirements of that test would be expected to take another version of the entry level test a week later. Failing that, the student might be asked to withdraw from the course. Perhaps this is a hard policy but it will certainly have an impact on educational excellence and expectations for students. Furthermore, such tests inform the instructor of the level of the students entering his class and which of them will be requiring additional assistance because of a weak background. The ease with which the MDT multi-digit tests can be prepared (and still maintain question quality and academic rigor) should help make computer-scored testing a more valuable tool for diagnostic feedback for professors to use to assist their students.

Some or all of these entrance prerequisite examinations need not be graded for points but simply evaluated to provide feedback to students. There is no need to create an additional and unnecessary work load for the professor. University level enrollees should be able to diagnose their own deficiencies given a minimum orientation from the professor. The student is capable of reviewing the computer-generated feedback and taking the appropriate remedial steps. Even in the case of making mathematical calculations, the computer can print the correct answer and the student's answer. If not within an acceptable range, the student should diagnose how he/she answered incorrectly.

If the preceding discussion appears to advocate more tests, albeit possibly shorter tests, this is exactly the intention. If mastery and competence are required, then more examinations will generally mean more time on the task and more review efforts by students. Numerous research results on frequency of testing show a heightening of student ability to answer questions correctly on later tests (See Section 8.3.3). Frequent testing and retesting is already a standard practice for employees in nuclear power plants. When the subject matter deals with an individual's chosen career or assigned responsibilities for which an employee is being paid, there is no valid excuse for not measuring up to expected minimum norms.

The MDT multi-digit testing innovation is not the only method upon which instructors or accrediting societies should depend. The MDT discrete answer method is not the solution to every educational problem. The point of this chapter is that the MDT method does offer significant previously unavailable advantages for the important educational requirements of our society.

9.4 Applications Of The MDT Innovation

9.4.1 Elementary Schools: The MULTI-DIGIT test method has applications in so many educational contexts, it is easier to identify the situations in which it is not applicable. The ones which come to mind are where students are unable to make the marks on answer sheets. Special Education (for either physically or mentally handicapped students) would probably make minimal use of this method. Likewise, preschool children and those in the first three grades of elementary school would probably not utilize the MDT innovation. This is not to say computer-scored testing is inapplicable in the lower grades. However, five or ten alternative choices might be totally sufficient for those applications. In the fourth through sixth grades of elementary education, the MDT method could become increasingly utilized. In these grades we expect our children to develop significant vocabularies they will use throughout their lives.

In upper elementary grades at the present time there is not a great deal of computer-assisted scoring except for standardized tests. However, there has been a considerable effort to get microcomputers into the classroom, because they can be useful tools for education. The machine also help free the teacher's time to spend on other tasks the computer cannot do. Traditionally, one of these manual tasks has been the grading of quizzes and tests. Many questions are given in fill-in-the-blank style, which requires tedious hand grading. Almost any high school student could do the hand grading for elementary school teachers, but we have not opted for this solution. Now, with the availability of the MDT discrete answer method to approximate the fill-in-the-blank style of testing, this tedious chore could be diminished for teachers in the fourth though sixth grades. Most schools already have at least one microcomputer. As the cost of optical mark readers decreases, scanners are becoming a relatively minor equipment purchase. One could be used for many classrooms or for an entire grade school. The scoring could be done within a matter of minutes and the students would have the advantage of prompt feedback and the opportunity to correct their errors. At the same time, the teacher would be free to spend additional time with students or grading written paragraphs, a much better usage of the teacher's capabilities and training.

9.4.2 Junior High Schools: The junior high or middle school educational levels emphasize still further points which have been made concerning the upper grades of elementary schools. In addition, many of the comments in the next section concerning high school applications are appropriate for the junior high and middle school levels.

9.4.3 Secondary Schools: It is a known fact that topics formerly taught only in colleges are now filtering down to the high school level. This reflects advances and shifts in our educational system, and also the fact that so much information is required for an adult life. It is only natural that the use of optical scanners and computer scoring, long established in our universities, should also become more prevalent in the high schools. Even today relatively few high schools, except those in the largest school districts or prosperous communities, have full-feature computer-scored testing. Many high schools have the simplest card or half-sheet scanners. Those machines usually mark only the incorrect answers and gives the total score. They cannot interface with microcomputers to accommodate the software requirements for the MDT Educational System. Expect those high schools to upgrade their machine-scored testing as they become aware of what can now be accomplished. Expect agreement among teachers, administrators, parents and serious students about the high priority of having the MDT Educational System for the improvement of education (see Chapter Ten).

One high school function is to prepare some students for college/university level education. For these precollegiate situations, comments in Section 9.4.5 and throughout this book have relevance for secondary education. High schools also have a responsibility to prepare other students to enter directly into the world of employment. For the preemployment situation, the following section is applicable. The MDT free-response discrete answer method can help high schools perform the tasks for both college preparation and employment preparation.

9.4.4 Training Courses: Job specific training is the principal form of education many individuals receive, whether in high school technical classes, corporate retraining, night school, adult education or correspondence-type courses. Often times it consists of on-the-job training or class work taught by corporation-paid instructors. Sometimes it is training and retraining sessions from unions or federal government programs. Whatever the format, the objective is the same: to insure that the student is capable of performing specific tasks for which he/she will be employed.

The earlier comments related to mastery learning and competency-based education are especially appropriate in this section. Many of the tasks taught in technical/vocational courses are competency-based and relate to tasks which are performed repeatedly on a routine basis. This can mean both the monotonous tasks associated with the assembly line or tasks which a worker does only once a week or once a month. Whatever the case, the basis of employment is the ability to perform a task again and again once it has been learned. The great majority of these tasks require the operation of one or more tools or machines ranging from screwdrivers, hammers and pocket calculators up to computers and multi-million dollar aircraft. Most of these jobs have numerous specific tasks which require visual recognition of parts or inputs. These lend themselves very well to the use of the supplementary pages of instructional material discussed in Section 5.11. Instructions for assembly, disassembly and repair are frequent elements in the educational process for job training. Many other tasks have specific vocabulary which will be used often with employees, fellow workers and supervisors. All of this information must be mastered. The use of the MDT multi-digit testing method appears to be a logical step.

It is anticipated that some schools will produce superior graduates and will be able to attribute part of that status to the rigorous education facilitated by the MDT innovation. Once this pattern has been established, it will be an essential requirement that the MDT innovation be utilized in any training program that wishes to have its graduates compete for available jobs. This will become especially true once employers start using the MDT testing methods to screen their job applicants and trainees. To get and keep a job, the prospective employee is expected to KNOW certain things.

9.4.5 University Levels and Above: For the levels of college education, graduate studies and training for the highest professions, many appropriate comments concerning the MDT multi-digit test have already been made in this chapter and throughout the book. People at these educational levels have no difficulty in understanding the nature of the testing method and how they must prepare for it. The most interesting aspect of the use of the MDT answer bank method in the higher levels of education will be the innovative ways in which the various disciplines will utilize the method. With the basic configurations of hardware, software and answer sheets available, innovative instructors will devise special applications. Some of them might even entail customized variations on the component parts. Multi-Digit Technologies Corporation has intentionally kept open the avenues for the design of additional answer sheets and the appropriate modifications of the software. Other specialist professors will use it as it is but in ways which a layman would not have foreseen.

9.5 Conclusion

The MDT innovation for educational testing has relevance for nearly every educational level and virtually every academic field of study. The applications of the MDT method are virtually unlimited. This chapter lends credence to the claims in this book that the MDT innovation will become standard educational practice in America five to ten years. However, the important issue of cost must also be analyzed.

Chapter Ten

Time and Financial Costs and Benefits of the MDT Innovation

10.1 Introduction

Our ultimate objective in using any educational innovation is that students learn as much or more than they would learn with other methods. Chapters Eight, Nine and Eleven focus on the improvement of learning. They indicate that learning is at least equal and possibly improved when the MDT discrete answer free-response method is appropriately applied. In spite of our idealism for improving education, the worldly realities must still be in balance. In terms of time and money, the costs and benefits of any innovation must be weighed very carefully when considering its true value. This chapter outlines the basic issues which should be studied in a detailed cost/benefit analysis, but it is not an attempt to quantify those amounts. The quantification will come at later stages after more teachers have used the MDT Educational System and after the initial establishment costs are better understood. The basic questions for this chapter are the following: What are the principal budgetary items influenced by the MDT Educational System? What actual cost estimates can be made? How do these costs and benefits compare with those of alternative methods?

Of considerable importance in any analysis is the specification of what is being compared. Because the MDT multi-digit method is a machine-scored approximation of a fill-in-the-blank test, it is most appropriate that it be compared with traditional multiple choice machine-scored questions and manually-scored fill-in-the-blank questions. The MDT innovation is expected to be the middle ground on many issues, but does it incorporate the best (or the worst) features of the other two methods?

10.2 Preliminary Issues: Hardware And Software Acquisition Costs

In order to have a functional MDT system, the various components discussed in Chapter Four need to be in place.

10.2.1 A Computer: It is assumed that every school in America has or will soon have at least one microcomputer, and that colleges and universities have a mainframe or several microcomputers. Any costs associated with these computers are assumed to be within the standard operating budgets and equipment purchases of schools. Given the wide variety of microcomputers compatible with the MS-DOS operating system, computer availability is considered a negligible problem. Even if a new microcomputer (everything, including a printer) is needed, the total price is already below one thousand dollars and falling.

Where test scoring facilities are centrally controlled, the salaries of the people operating the machines are assumed to be included already within the basic administrative costs for support personnel for the educational process. In cases where individual teachers would be expected to operate the microcomputer and process their own tests, the comparisons in Section 10.4.3.2 will be between the time it takes them to use computer scoring and the time they would have otherwise used to handle their test grading.

10.2.2 Optical Scanners: Optical mark readers (OMRs) of various qualities are available at prices from about $1,000 to over $60,000. Not all brands and models can offer the complete range of MDT testing features (see Section 4.2 and contact the MDT Corporation). If a school already has a full feature scanner for use with the five-choice type of questions, there is no additional OMR cost for the MDT method. If no scanner or only a rudimentary stand-alone reader is available, the cost of an MDT compatible OMR is low enough (under $4,000 for a sheet reader) that average school districts could soon purchase an adequate machine. A darkest mark discriminating sheet reader is available for under $4,000. A less sophisticated card reader sells for $1,100. If this purchase would be done eventually for multiple choice testing, the MDT method costs nothing extra in equipment. Just be sure to purchase one that can support the MDT innovation. You can spend the same money for one that is not compatible. Contact the Multi-Digit Technologies Corporation for details and recommendations.

10.2.3 Software: Test-scoring software from the MDT Corporation is priced competitively. It should be assumed that any school with the ability to acquire the necessary computer and scanner will be able to meet the relatively modest prices to purchase the MDT test-scoring package plus the List Maker and technical support. There are too many pricing options to list in this book. Large universities and corporate training divisions have needs distinct from those of small high schools. The pricing is appropriately scaled.

10.2.4 Summary of Hardware and Software Costs and Benefits: The costs of acquiring an operational hardware and software system are surprisingly minor. Many schools already own an appropriate computer and scanner. In those cases there are no costs except to acquire the MDT software.

On the benefits side, the microcomputer and the optical scanner can serve a variety of additional functions. The scanner, coupled with appropriate software, can be used to simplify the basic administrative work within any school, all with significant financial savings. Specific packages exist for attendance forms, bookkeeping procedures and the preparation of reports which are constantly required by state and local authorities. There should be no doubt about the utility of OMR technology for the improvement of education.

10.3 Operational Costs And Benefits

The major cost/benefit issues are more clearly evident in relation to the day-to-day and the semester-to-semester operational use of a machine-scored testing system. The expendable "paperware" is a commodity and a recurring expense that can vary with the amount of usage and the requirements of the hardware system.

10.3.1 Answer Forms: In the initial stages while relatively few multi-digit tests are given, the cost of MDT answer forms is higher (probably by thirty to eighty percent) than the costs of five-choice answer forms purchased in large volume for the respective OMR machines.

Eventually, those prices will be totally competitive. All scannable answer sheets are more expensive than blank sheets of paper used for fill-in-the-blank style tests, but special inks and printing are needed for computer scoring. Costs of four to seven cents per student per MDT test would be typical for beginning users. Twenty-five students multiplied by six tests per semester multiplied by six cents per sheet would cost $9.00 per course per semester initially. With forty questions per test, the cost is less than two tenths of one cent per question scored, including tallies, item analysis and statistical calculations.

10.3.2 Lists: The reproduction costs of lists are basically the price of photocopying or inexpensive printing. Prepared MDT lists on paper cost a few dollars for reproducible master sheets. Prepared lists on microcomputer diskettes cost $5.00-$20.00, depending on the source and complexity of the list. These are one time costs. As lists become readily available from a variety of sources, the cost of lists will become almost negligible. Furthermore, even in the initial semesters of use, instructors spend relatively little time in the preparation of a list. The cost of this time should be considerably less than the time spent over a period of many semesters as professors try to think of the four wrong answers to go with each new question they want to incorporate into their examinations.

10.4 Question Quality And Time To Record Answers

Three factors (students, the instructor and bank of possible answers) relate differently to each of the three test methods being considered: multiple choice, MDT multi-digit and fill-in-the-blank. The comparisons which follow refer only to the discrete answer subject matter that could be appropriately tested by all three methods.

10.4.1 The Bank of Possible Answers: For equivalent questions, the fill-in-the-blank method has an advantage in that the possible responses to a question are infinite. The student selects the answer from the terms within his/her mind and writes it on the paper. The MDT multi-digit method can have a very large selection of possible responses which, when large enough, approaches the difficulty level of the fill-in-the-blank method. Shortening the lists to fewer than one hundred terms (or even fewer than two hundred fifty terms) will greatly limit the effectiveness of the answer bank method in this important criteria.

For the traditional multiple choice questions, there are usually only five (and infrequently ten) alternatives utilized for each question. Therefore, there is a very limited selection, from which one answer must be correct. Concerning this first criteria, (the size of the bank of possible answers), fill-in-the-blank is considered to be the best, with the long-list method being a close second. Multiple choice lags far behind.

10.4.2 Student Speed for Deciding and Recording Answers: The speed for encoding the answers to questions is fastest for five-choice questions. The fill-in-the-blank method can be equally as fast as the five-choice method when the answers are written on the test pages, compensating for the need to find the appropriate place in which to mark the five-choice answer on the answer form. The time for deciding upon an answer is dependent in part on the question's difficulty. In general, however, the five-choice method is faster than the fill-in-the-blank method. The long-list method is the slowest because after thinking of the answer the student must go to the long list to obtain the code number. Also, the marking of the three-digit code number takes about three times as long as a single mark. The length of time for marking is offset by the fact that an MDT discrete answer test needs fewer questions to differentiate the performance levels of students within a class. Furthermore, it is common practice that many students finish their multiple choice tests long before the allotted time has expired. They generally have time available for taking longer to mark their selected answers. In terms of cost to the school district, there is no difference between these three methods. A student's time, although not something to be frivolously wasted, is a commodity to use for the best educational purposes as deemed fit by the school. There is no disadvantage or financial cost in the requirement to encode the multi-digit answer sheet.

10.5 Personnel Time

Instructor Time: The major cost factor within any school is teachers' salaries. In the context of educational testing, there are four important criteria: speed of making a test; speed of grading a test; speed of analyzing plus recording the results; and integration of the system.

10.5.1 Speed of Making a Test: The fastest questions to write are those for the fill-in-the-blank method. The teacher merely needs to think of the stem of the question and then leave a blank space for the answer. In the MDT method, there is some time spent in the list preparation, but as has been pointed out before, long lists will become readily available and are thoroughly reusable for many tests. Given that an appropriate long list is available, the instructor can write the questions for an MDT multi-digit format equally as fast as for the fill-in-the-blank method.

Question writing for the five-choice method, given that the questions are to be of the same discrete answer style as those for fill-in-the-blank and MDT answer bank method, are considerably more time consuming. Not only must the teacher formulate the question in his/her mind, write it and insert the correct answer as one of the alternative answers, he/she must also think of four alternative answers (foils or distractors). The quality of these foils is a source of major complaints concerning the desirability of five-choice questions. If the four distractors are hastily made and of poor quality, the value of the question is greatly diminished and education suffers. To generate four reasonable alternatives is a very time consuming task. Furthermore, some of these foils are sometimes intentionally tricky and potentially even misleading. This is another source of criticism in the five-choice mode.

An additional difference between these tests is that all of the five choices have to be written down, typed and proofread, then subsequently read by each student. In a sixty question multiple choice test there are three hundred answer options. If there are four tests in a semester, this means one thousand two hundred answer options. In this context, a list of six hundred or even nine hundred ninety-nine answer options (prepared once or even purchased) does not appear to be such a daunting problem.

On the criteria of speed of generating questions, the fill-in-the-blank and MDT long-list methods are very similar in time commitments for the teacher. In contrast, the five-choice questions are by far the most time consuming and potentially the most problematic from the educational point of view.

10.3.2 Grading the Tests: The computer-assisted grading of five-choice and MDT discrete answer tests is equally very fast and convenient. Manual grading of fill-in-the-blank questions is extremely slow and time consuming. This extreme slowness of grading is by far the major drawback to the use of fill-in-the-blank questions. Manual grading is an excessively inefficient and poor use of the skilled labor available from instructors. The teacher's time would be much better spent on extra tutoring for students or for grading essay questions and student project work.

The causes for the extreme slowness in hand grading include students' handwriting, decisions as to whether or not incorrect spelling will be accepted or if partial credit will be given. As all instructors know, when the hours drag on in this type of grading, human frailties come into play and there are possibilities of inconsistent grading or adding scores incorrectly.

As an example, consider a class of twenty-five students taking a test that includes forty questions which could be asked virtually the same way for each of the five-choice, fill-in-the-blank and MDT multi-digit methods. After an answer key has been prepared, the computer scoring would take ten to twenty minutes (for delivery time to the grading center or for passing sheets through the scanner). Manual grading of handwritten answers could entail one to three hours, depending on the arrangement of the questions on the page or pages of paper. At a teacher's salary of $10.00-$15.00 per hour, the cost would be between one and four cents per question. That cost is ten to twenty times higher than the estimated cost of the scannable sheets as calculated in Section 10.3.1.

Depending on the frequency of testing and the number of courses taught, this difference in time spent for grading could result in literally scores of hours and hundreds of salary dollars spent each semester by each instructor on tasks which can be done easily by machines. Multiplying this by the tens and hundreds of instructors in a school or university, the costs of the scanners and software could be recovered in a year or two. Considering the thousands and tens of thousands of instructors within any major political unit such as a state, the savings in instructors' time each academic year can reach millions of hours and dollars to be reallocated in various ways for the improvement of education. And this is only part of the savings.

10.5.3 Grade Analysis and Feedback: The fill-in-the-blank method is also wasteful in that it does not generate valuable statistical data to assist teachers in the evaluation of students. To simply obtain a single numerical grade for each student is a gross waste of data collected from any academic test. However, it would take countless more hours and dollars for the teacher to tabulate responses as given for each question. Such tabulations (called item analysis) are desirable so better questions can be formulated in the future. Also, the instructor does not usually give subdivision scores for the students, so they have only limited feedback as to why their grade was a "B" or a "C". Considerably more classroom time must be utilized if the instructor is to go over each test and explain the different questions to the students.

On the other hand, both the five-choice and MDT multi-digit methods have the full power of computer-assisted tabulations and feedback. Item analysis has long been recognized as a major benefit from computer-scored testing. The ability to give specific tabulations for each student is also very valuable. Furthermore, the computer can automatically enter the students' grades into appropriate grade book columns and make special tabulations. Additional costs of teachers' time for these desirable reports further accentuate the financial disadvantages of the manually scored free-response discrete answer method in contrast to the machine-scored MDT format.

Concerning computer-generated feedback for each student, the MDT innovations are clearly superior to the much more limited output from the five-choice method. Only a very sophisticated and costly system, e.g., the CADE System in Scandinavia, can come close to the computer-assisted feedback of the MDT method.

One excellent sort of feedback is to return the graded tests to the students for review and even to keep. Handing back fill-in-the-blank tests is possible because those questions are relatively easy to write. Future tests need to be different from those which have been given into free circulation among the student body. The handing back of five-choice questions is not a normal practice because of the considerable time spent writing decent questions. It can be done, but multiple choice tests tend to be closely guarded by instructors. This is not a problem with the MDT method, first because the questions can be generated easily and second because the computer can give very good feedback without allowing students to obtain an actual copy of the full test. The quality of the computer-generated feedback is greatly enhanced because the long list of discrete choices can be maintained in the computer memory and utilized in making the responses to the students.

With regard to the criteria of analysis and feedback, the MDT multi-digit method demonstrates clear superiority, the five-choice method is in second place and the fill-in-the-blank method is in a disasterously low third place.

10.5.4 System Integration: Time and money can be saved through the integration of the various educational procedures and components. Manual scoring of fill-in-the-blank tests offers no time-saving integration. The scanner and computer assistance could be equally beneficial for the multiple-choice and MDT answer bank method, except that most multiple-choice scoring programs do not integrate with grade books, test makers, etc. In contrast, the entire MDT Educational System is fully integrated. For example, the answer banks created with the MDT List Maker program are used for printed lists, micro-computer diskette files for retrieval of the words responses in the feedback sheets, mainframe computers files for the MDT4 program, and additional ways not yet released. Also scanner-scored sub-totals can be passed directly to the MDT Grade Book where additional tallies, analyses and reports are generated. Many other examples could be given of MDT system integration already operational and being developed. In summary, fill-in-the-blank is the worst option for integration and multiple-choice is second. The MDT techniques are now and are designed to remain the most beneficial in time and cost saving through innovative integration of OMR and software technology to facilitate the work of teachers and enhance educational activities.

10.6 Additional Benefits

One additional advantage appears to be the decrease in the amount of typing time required to make each test, given that the single, reusable long list can replace the many short lists of five to ten responses which continually must be retyped for each question on each offering of a standard multiple choice test. Word processing and computer technology can further diminish the secretarial work.

Computer run-time for the grading of MDT tests was initially ten times the average cost for multiple choice tests, using the cost scales at Illinois State University. The new mainframe program called MDT4 has diminished the cost dramatically to a level now quite similar to grading an average five-choice test.

A further benefit concerns the generation of computer feedback to go beyond the student and the instructor. Modern educational units require considerable reports to be generated for administrative use. Parents also desire reports from schools, and society (represented by the elected school board or college directors) desires to know how the school stands in comparison to other schools. In terms of the amount of specific detail in the reports, the detail is a) highly individual when given to the student, b) at class level for the teacher, c) at school-wide level for the administration, d) at a child and school comparison for the parents, and e) a comparison just between schools and educational systems at the society level. In other words, the amount of detail decreases as it goes through the hierarchy from student to society. On the other hand, the number of students represented in each report is only one student at the individual student level and yet becomes thousands and millions at the statewide or nationwide society levels. The computer is extremely adept at generating quantitative data, some of which is the basis for schools to claim their government subsidies or their fair share of tax revenue. Likewise, it is the basis on which a society can judge the level and output of any particular school system. In terms of the cost/benefit analyses, computer generated statistics, beginning with the recording of data on scannable sheets, are extremely efficient and cost justified.

10.7 Conclusion

There appears to be strong evidence supporting the use of the MDT educational innovation in relation to financial and time costs and benefits for the student, teacher, school and society. When put into general use, the MDT method with computer scoring should result in improved education at a cost of only a couple dollars per student per course per year. In compensation, there will be substantial savings of time for the teachers who should be able to devote more of their time to better instruction in a variety of ways, including the very important efforts to encourage student writing activities across the curriculum. Once again, it is emphasized here that the MDT method is an additional educational tool which should yield benefits. The intention is not to replace any of the existing testing methods, but to improve the quality of education and to do it with greater financial savings than costs. Repeating what has been stated previously, **there is no indication as to why the MDT method should not become an integral part of educational testing in almost every level of education and in practically every discipline.** Anyone questioning this or other statements is encouraged to conduct and publish rigorous research to refute or substantiate issues raised throughout this book. It is through such activities that the best aspects of all parts of educational systems can be brought into play for the improvement of education everywhere.

Further research will clarify and substantiate the advantages offered by the MDT innovation. Numerous hypotheses could be generated from these pages for use in a variety of graduate theses to fully document and quantify these comparative costs and benefits. It appears the MDT method incorporates the best from both sides, that is, computer speed from the five-choice method and academic rigor from the free-response discrete answer type of testing.

Chapter Eleven

The MDT Innovation and Higher Order Learning

11.1 Introduction

This chapter is an attempt to summarize the ways in which the MDT testing method relates to some major educational issues. It is not intended to be a treatise on educational theory nor a detailed summary for people who are unfamiliar with the various topics.

In this chapter it is assumed the MDT multi-digit method does indeed function as a machine-scored approximation of fill-in-the-blank questions which require a high degree of recall for answers. Discussions about that issue are in Chapters Eight and Nine. This chapter relates to what is commonly referred to as the higher orders of learning, as frequently typified by the widely known taxonomy developed by Benjamin Bloom. Although alternative terminologies proposed by other experts in the field of education are presented below, this chapter is not intended as a debate concerning those issues.

Nor does this chapter deal with the psychomotor aspects of learning and individual development. The MDT answer bank innovation is aimed at cognitive and affective learning, these being the factual knowledge and the values aspects of individual thinking, respectively.

11.2 Hierarchies Of Learning

The classic hierarchy of learning as proposed by Bloom is illustrated in Figure 11-1, along with somewhat different systems proposed by Bruner and Ausubel. The diagram oversimplifies the similarities between the systems, and each reader should refer to the original authors' works for full explanations of their terminology. Nevertheless, there are underlying similarities between them. Without doubt a good education should help an individual develop all of these kinds of learning. In relation to the MDT multi-digit innovation, there are two primary considerations. First, how can the MDT answer bank method, with its evident powers at the levels of knowledge, comprehension and application, promote the higher levels of learning? Second, can the MDT method actually be utilized with the higher levels?

In the terminology of the three taxonomies, it is clear the MDT discrete answer method can be utilized very effectively when rote learning or knowledge or remembering is the objective. In other words, the lowest level means "know it", in the sense of factual recall.

The three hierarchies have another level called comprehension, recognizing or meaningfulness. As opposed to the lower level, comprehension implies that the individual understands something about the topic studied. An illustration is the ability to translate or to express in different words something which is known in the lower rote learning format. It is more than a regurgitation of knowledge; it implies that the individual understands the meaning of the knowledge. The MDT method is certainly able to adequately test for comprehension. For example, when a definition other than one which is printed in the textbook is given in a test, the student should still be able to realize what the appropriate terminology is and select the term from the long list. In the five-choice mode, the term could be given and the five choices could include one phrasing which would be an alternative to the definition as given and learned in the textbook, with the other four alternatives being incorrect.

Bruner's use of the word "recognizing" causes some confusion. In the sense used in the previous paragraph, it can be equated with comprehension and meaningfulness based on the lower level of knowledge and remembering. But when some term cannot even be remembered (that is, truly recalled), the recognition of that term among five choices is certainly not at a higher level. The terms recognition and recall are major discriminators between the five-choice and the long-list fill-in-the-blank style questions. The relative value of recognition (identifying an answer out of a small group of suggested responses) versus recall is an issue that must be resolved within the educational goals of each discipline. The requirements of recognition versus recall is an issue for each individual instructor and student. In the

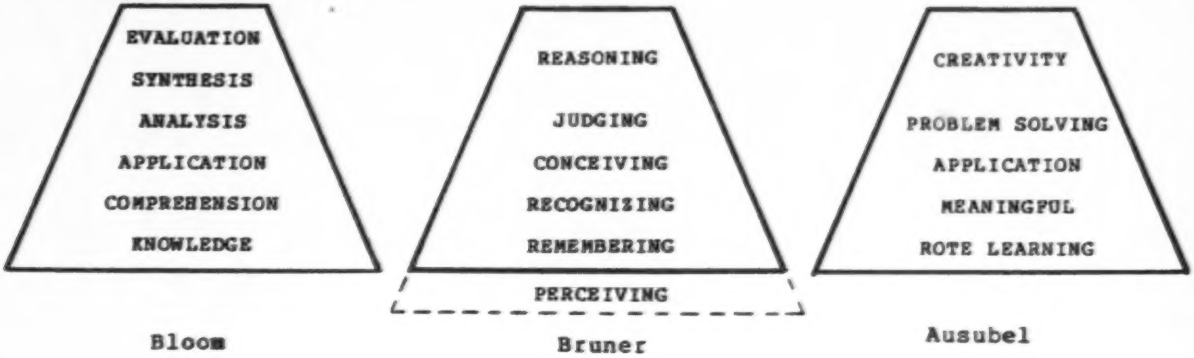

Figure 11-1 Comparison of Hierarchies of Learning

EVALUATION
SYNTHESIS
ANALYSIS
APPLICATION
COMPREHENSION
KNOWLEDGE
Bloom
REASONING
JUDGING
CONCEIVING
RECOGNIZING
REMEMBERING
PERCEIVING
Bruner
CREATIVITY
PROBLEM SOLVING
APPLICATION
MEANINGFUL
ROTE LEARNING
Ausubel

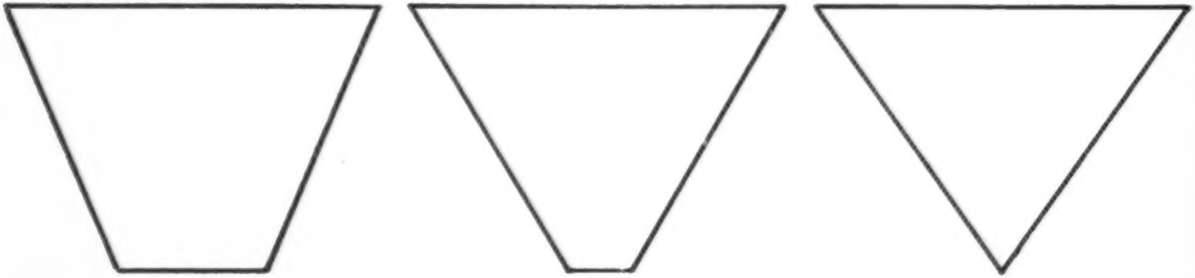

Figure 11-2 Instability Because of Insufficient Base

nature of a hierarchy, it appears recall should be placed at a higher level (within knowledge or rote learning) than recognition.

The third level, application, requires a slightly greater degree of abstraction on the part of the learner. The student must be able to manipulate various facts and arrive at a solution. Whenever a solution can be expressed as a single term or a few terms which could be alphabetized in a long list, the MDT answer bank method could be properly used. Also, any application question for which the answer is a numerical value could be easily accommodated with the MDT Educational System for computer scoring. Application is clearly within the realm of operations of MDT multi-digit testing.

The higher orders of learning require progressively more thought and lead to more abstract answers. Those answers are generally not well suited for expression as single terms or short phrases in an alphabetized long list. In the case where the final outcome is a numerical answer, the MDT method could very well function. However, frequently the instructor desires to follow the thought patterns as expressed in the equations and calculations so as to observe how the student proceeded into the various stages of creativity with judgment. This is analysis and evaluation. One way in which the MDT techniques can relate to this is when a calculation problem has a specific solution which the instructor can subdivide into a step-wise series of questions. A corresponding series of answers could be obtained, revealing the series of higher level thought processes. For example, the first steps of calculations, the identification of the correct formula, the listing of the data values, and naming the components to solve a problem could all be placed into MDT discrete free-response answers which could be machine scored and even printed out for the professor to evaluate.

Considering the great diversity of the academic disciplines, specialist instructors in other fields will undoubtedly provide examples of innovative use of the MDT answering system for recording and grading higher order questions.

11.3 Relationships Between Higher And Lower Order Questions

A great deal is said in favor of educational techniques which promote higher order learning. This author advocates those efforts and in fact attempts to involve his own students by using alternative testing techniques including written short answers and essays.

On the other hand, too little seems to be said in favor of the lower levels. For many persons' employment and livelihood, the two highest levels have only partial relevance. For them, the level of application (and possibly analysis) is the maximum that is required. Companies frequently have retraining sessions to help their employees learn and function with appropriate skills. These employees do not devise or synthesize new systems. Their employment is on the basis of being able to do specific jobs which are presented to them. These are not necessarily menial jobs which could be performed by machines or computers. They are tasks which require human eyes and human hands and appropriate responses at critical times. However, they do not require everyone to be a creative genius.

Sometimes it appears as though cognitive learning is the lowly stepchild of the hierarchies. Perhaps insufficient attention is given to it. The learning of factual material may not be a Cinderella who will rise above her sister levels of learning, but she is certainly on equal footing. The upper levels are dependent upon well established lower levels. This is why the diagrams of hierarchies of learning (as in Figure 11-1) are frequently drawn as nested circles or as pyramids, clearly revealing the solid base levels of knowledge, comprehension and application. Without this base, the pyramids would look more like those in Figure 11-2. The stability of such a hierarchy would be questionable both in the diagrammatic form and in reality.

It is common to hear people criticizing the learning of knowledge, i.e., the "facts". Memorization is out of date; learning to think is what schools should teach. Maybe "thinking" is the ultimate goal, but **what to think about** is also a fundamental issue.

The simple reality is this: Students are unable to properly perform the higher level functions unless they have the factual knowledge to be applied or manipulated in their analysis, synthesis or evaluation efforts. There is almost a Catch-22 situation in these circumstances. Precious class time should not be spent on teaching specific facts; it is more important for the teacher to interact with the students in terms of higher order thinking and evaluation. However, when it comes to having tests, sometimes the students lack the specific facts they need to utilize and apply in their syntheses. Subsequently, students can criticize the educational system for not having prepared them for some tasks society expects them to perform. But yet if we spend too much time on specifics, when do we get to the higher levels of thinking?

The commonly disjointed sequencing (or lack of sequencing) of many university and high school courses can result in no overall game plan for using the levels of learning. Students need to gain exposure to all of the different levels of learning that are required in proportion to their future job requirements. Sooner or later almost everybody is faced with learning some specific knowledge. This is often in training programs by companies. Whenever and wherever such learning occurs, the availability of the MDT innovation and the ease of its use should be beneficial to help resolve these difficulties.

Another issue is the scarcity of good quality, higher order questions by any means other than essay types of answers. A look at the machine-scorable questions provided in teachers' manuals from many textbook companies reveals relatively few at the higher orders. Many questions provided in a five-choice context are at the base levels and could be directly adapted or slightly modified to function equally well with the MDT multi-digit method.

Furthermore, the levels of the supposedly higher order questions change with exposure to those questions. Specifically, once a question with a five-choice answer has been divulged, students can learn the answer to the question rather than learn the higher order techniques for solving the question. In other words, the same question or even a similarly phrased question could not be asked twice because the students have been alerted to the specifics of the answer. In some cases, it can even be simplified as far as becoming a case of rote memory. "For the tough question about [topic Q] . . ., the clue to the answer is [RST] . . ." Perhaps this is an example of the Hawthorne effect in which a change of the environment (in this case, prior exposure to the nature of the questions) will result in different behavior by the students. This technique appears to be part of the strategy of courses designed to help students perform better on standardized national tests such as the ACT and the SAT. In essence, for higher order thinking to be assessed, questions must deal with new situations that actually require evaluation and synthesis. Anything specifically dealt with previously could be relegated to recall.

In the same light, tests of intelligence are not intended to make people smarter. If the person had the opportunity to take the same test twice with a chance to study the test between the two examination dates, that person would undoubtedly register a much higher IQ. Access to higher order questions does not make a person more intelligent.

11.4 Higher Order Questions And Guessing

In the case where higher level questions are formulated in a multiple choice mode, students can correctly put down one answer out of five without actually solving the problems. Apart from the twenty percent chance for a lucky guess out of five, students may also solve problems only partially. When all but one of the choices are eliminated, the students do not need to finish the problem. The situation is even less appealing when the student, without solving the problem at all, is able to improve the probability of a correct guess simply by eliminating answers which are highly unlikely or clearly incorrect. This raises questions concerning whether or not "the process of elimination" is an important thought process. While successful elimination can indicate good reasoning in some situations, there are relatively few situations in real life where personal actions are based on choosing a likely answer out of a selection of five offered alternatives.

The debate concerning the applicability of multiple choice questions for higher order learning has been waged for several decades. Research indicates that the five-choice method is acceptable WHEN THE MULTIPLE CHOICE QUESTIONS ARE PROPERLY AND CAREFULLY FORMULATED. But this is not the end of the story. As stated earlier, once these questions are available to the students, their level in the hierarchy is dramatically reduced. This leads to protective hoarding of these precious good questions. The difficult formulation of new multiple choice questions which adequately evaluate higher levels of learning is a daunting task few school teachers or university professors are willing to perform repeatedly for every test they have to give. The success of the five-choice standardized tests is directly related to the large budgets for developing new questions. Therefore, while it is possible for multiple choice questions to be adequate evaluators of higher level learning, there is something lacking in actual practice.

11.5 Using Answer Banks With Nominal, Ordinal And Interval Levels Of Measurement

In statistics the terms nominal, ordinal and interval levels of measurement are used in relation to the quantifiable nature of the phenomena. The nominal level, based on names without any insinuation of superiority or order of one to another, very appropriately matches the use of the MDT lists. For example, the chemical elements of helium, chlorine, oxygen, etc. have a random order when alphabetized. Alphabetical order is desired so the responses can be found quickly, like in a dictionary. Otherwise, the terms are randomly arranged. The MDT answer bank method essentially offers almost unending lists of nominal choices for free-response discrete answers. Therefore, the multi-digit answers are able to approach higher levels of learning because the need for recall is combined with the thought processes for deriving free-response correct answers.

At the ordinal level phenomena are placed in a rank order such as from least desirable through average to most desirable. The MDT techniques function very nicely when students can find the desired answer within the order imposed by the responses, even though there is no alphabetized order. Therefore, questions which use semantic differentials or other ordinal classification systems could easily function with the multi-digit format for recording answers. As long as the order is maintained, so the student is able to locate the desired response and code number, each list can be as long as desired. In contrast, the machine-scored multiple choice method must stop at five or ten ordered responses.

At the highest level of measurement, interval data (and also ratio data) utilize numeric values in which the interval or spacing between each number represents specific quantities. This is frequently used in the exacting laboratory sciences. As discussed in Section 5.7, the MDT method is totally capable of recording numeric interval data and maintaining the precision specified by the instructor. The multiple choice method lacks this capability.

11.6 MDT As A Promoter Of Higher Order Learning

By using the MDT method and the associated computer-scoring techniques, it is possible to stimulate an improvement in higher order learning. This occurs in two particular modes: (1) improvement of the cognitive base; and (2) the task allocation of instructors' time.

11.6.1 Improvement Via the Cognitive Base: As stated earlier, a strong cognitive base is required for effective higher order educational activities by students. Assuming higher order learning will utilize essay questions or paragraph types of answers, it is important that the student has the appropriate vocabulary and factual knowledge to write an effective essay. Much of the cognitive information is in textbooks. To get the student to study and learn it is often simply a matter of making that information valuable in the determination of the course grade. Although ideally students should want to learn for the sake of learning and self-improvement (a beautiful "carrot" stimulus), it is frequently the "stick" of testing that drives their educational efforts. For the cognitive information, the MDT answer bank method, when properly utilized in conjunction with other machine-scored testing techniques, can stimulate cognitive learning without overly burdening the instructor.

There are a number of research hypotheses associated with the improvement of the cognitive base. For example, does the potential for "picky" or highly specific content questions in a free-response discrete answer format (multi-digit or fill-in-the-blank) have a positive, negative or no influence on getting students to study materials more carefully than if they only had to answer with an essay exam? Since the MDT multi-digit answer bank method of computer-scored testing is able to give the high quality feedback for instructors, and if this feedback is used properly, the answer should be a definite "yes" for a positive influence. Students throughout the centuries have learned they need to be able to respond according to the methods the professors select for their questions.

Another primary research hypothesis is whether the quality of essay answers will rise because students have a greater mastery over the factual materials that need to be incorporated into good essay answers. This hypothesis might be harder to test than it initially appears because essay exams are by their very nature the cornerstone of "subjective" evaluations. Unless painstakingly controlled and quantified, it is a subjective judgment as to whether or not an instructor is actually acknowledging the factual content evident in essays or if the instructor is focusing on lines of thought regardless of quality and quantity of the factual information. This appears to be a natural topic for further research now that machine scoring of discrete answer recall questions is available by the MDT method.

One of the major difficulties in grading essay questions is when well-expressed answers include glib statements or very little substance. In an oversimplified example, an essay about the American Civil War and the activities of the presidents of the Union and the Confederacy, without mentioning those two gentlemen by name, should make an instructor wonder whether or not the student actually has much grasp of the history of that period. (Just for fun: Do you **know** those two names? One is easy: Lincoln. But can you **recall** the other? Many people cannot. They could answer it in a five-choice situation, but **recognition** does not help in essay situations.)

The highest of the higher orders is a realm in which well-argued and factually substantiated points of view in disagreement with those of the instructor or textbook are potentially as valid as ones that have been the established thinking in a given discipline. "Evaluation" is only a stones' throw from "opinion". Once again the cognitive foundation for offering these opinions could spell the difference between an "A" and an "F". Creativity without a sound base could be either a stroke of genius or foolhardy incompetence. Regardless of whether the student agrees or disagrees with the established thinking within a discipline, there should be some substantiation or argumentation on the basis of what has been studied in a specific course. If this were not the case, instructors would have to give a passing grade for every statement (no matter how foolhardy) presented in the name of evaluation or creativity or reasoning. Obviously, simple opinion is not sufficient. A U.S. Marine guard of the embassy in Brasilia expressed it this way: "Opinion is like a [navel]; everybody has one." He referred to a less polite part of the body to express his low regard of opinion.

What is more important is to have **informed opinion.** The President of the United States is faced daily with decisions that must be made on the basis of his and his advisors' opinions. But the more informed those opinions are, the better should be the decisions. Once again, the lowly cognitive levels demonstrate their great importance. The MDT contribution to improving the cognitive levels should, therefore, yield improvements in the higher orders of learning.

11.6.2 Task Allocation of Instructors' Time: In Chapter Ten there is a discussion of the cost of the instructor's time spent grading exercises and tests which could be adequately handled by computers, scanners and software. If the time saved is devoted to reading essay questions, grading student projects or interacting with students, higher order learning could be greatly improved. In America today there is considerable interest in "back to basics" and also in a program called "writing across the curriculum". The MDT method does not conflict with either of these ideas. In fact, it is strongly supportive of both. The movement to get students to write more in all of their disciplines is an uphill battle which could be greatly facilitated if the extra hours for grading the written materials could be obtained by releasing those instructors from other duties. Cost structures do not permit the decrease of teacher in-class work loads or the hiring of assistants. But an extremely easy and highly cost effective method of finding more time for teachers is in the use of optical mark readers for test scoring. Any school which does not avail itself of machine-scored testing capabilities is turning a blind eye to a low cost but extremely efficient system that will gain time for teachers to do the tasks for which they are trained. School boards, PTA's and teachers unions should all agree on a higher priority for machine-scored testing. This is doubly true now that the MDT fill-in-the-blank style testing has overcome at least some of the limitations of five-choice questions.

These hardware and software developments are not intended to give vacation time to instructors. But as has been shown in the case of many different professions, when given equal work loads, the people who perform more interesting tasks have greater job satisfaction than those who perform mundane and repetitious items. In the educational context, this is the difference between grading essays, reports and projects instead of grinding through literally hundreds of filled in blanks and answers A through E recorded on tests which could have been machine scored. Furthermore, the innovation of the Short Answer SA feature (Section 7.7) further facilitates the inclusion on tests of subjective essay questions requiring written answers.

Students need to be asked to perform in both the objective and subjective modes. Without this requirement, the tendency is for students to modify their studying to learn in only one way in order to pass a specific mode of test. This is generally to the detriment of the learning promoted by alternative testing methods. To substantiate this statement, simply give students an essay test when they have been told the test would be in the multiple choice mode. The complaints would be heard all the way to the administrative offices. However, if asked to prepare for both methods, the students study for both. They might also complain, but this time because of academic rigor, not misinformation that lead them to prepare for essay answers. If it were easy to study for both methods of testing, students would not chafe when asked to do so. But then, going to school was never intended to be a lark simply for fun and games. Students are there to learn something, and the academic rigor in American schools can certainly bear an increase.

We must remember that sometimes it is the professors who do not want to use a variety of testing methods. This is where the MDT innovations for machine-scored testing are so capable to provide the interface and help the instructor gain time so that all modes of testing can be accomplished.

11.7 Conclusion

This chapter has attempted to show how the MDT method can relate to the various levels of learning. There are numerous ways that individual instructors can utilize the MDT method to serve their particular needs. It should be highlighted that the MDT method is supportive of efforts to encourage students to write. At present, computers are unable to evaluate essays. Nor are they likely to do so in the foreseeable future, because when a computer is capable of evaluating an essay it will also be able to write one and there will be no need for humans to write essays.

Cognitive learning is very valuable. However, it must be kept in its proper place. Emphasize it where appropriate, test for it and get it over with in each testing situation. This will then allow for the other levels of learning to be properly evaluated and included in the testing situations. A mixed balance is very important, and the MDT innovations are designed to expand and assist those aspects of the learning process.

Chapter Twelve

Research and Development: A Conclusion That Opens Doors

Many avenues for educational research have been indicated in the previous chapters. Rigorous and critical examination of the MDT testing technique now requires the talents of numerous researchers. Interesting findings are sure to be made as the multi-digit methodology is applied to the full range of disciplines and educational levels. Simultaneously, the user base will broaden as the MDT method is made compatible with more hardware, software and examination paperware. This type of research and development will have great impact on educational improvement because it is immediately applicable, reaching the actual learners in their schools and strengthening a broad base for further growth.

The research will also have impact on the established testing methods. During the mid-1980s the discussions about the role and validity of tests based on the five-choice format have attracted national attention. Conferences, such as the activities of FairTest, on the adequacy of standardized tests (SAT, GRE, ACT, Iowa, etc.) have provided platforms for professionals to air their doubts about current evaluation practices. David Owen's (1985) book None of the Above is a well documented (541 footnotes) piece of modern "muckraking" in the desirable sense of the word. The Educational Testing Service (ETS) and its Scholastic Aptitude Test (SAT) are the targets. Owen's book is essential reading for anyone concerned about machine-scored tests. It is apparent that some of the deficiencies cited by Owen could be rectified by the MDT multi-digit method, while still preserving the ability for machine scoring of millions of answer sheets.

Another form of research and development goes beyond the user base. Expanding computer technologies and new testing methodologies will open additional horizons.

Multi-Digit Technologies Corporation already has several additional innovations on the drawing board; each could become a separate chapter in future editions of this book. It is premature to disclose those ideas today, but they will be compatible with the existing MDT Multi-Digit Testing System. First notification of availability is through the MDT Bulletin and to users.

This conclusion chapter, therefore, is actually a continuation. There are no "new beginnings;" even the MDT innovations have a firm base upon previously existing equipment and testing methods. Nor are there any "closed cases." All research and development efforts are a continuation toward improvements. For this objective of growth and development, the MDT Corporation encourages you to try MDT multi-digit answer bank testing in your classroom. Your reactions and those of your students would be appreciated. The feedback you provide on this book and on the MDT testing methods will lead to further innovations and improvements.

Educational improvement is one of the few topics of agreement by politicians, business leaders, unions, teachers, administrators, parents and taxpayers. Excellence in education pays big dividends financially and culturally for both society and the individuals. The MDT innovation fits naturally into America's overall present and future educational picture. Applied computer technology, increased academic rigor, improved feedback for students and substantial cost savings are all necessary components for modern and future educational excellence. These components are all present in unique and powerful ways in the MDT multi-digit technique.

Appendix 1

Program Documentation and Installation Instructions for MDT4 with F1 Answer Sheets

These test-scoring instructions are written for technical staff using the mainframe program MDT4 with the MDT answer sheets F1 or D1 for scanners by NCS or Cognitronics, respectively. Both answer sheets have fifty three-digit plus seventy-five five-choice questions (50:3D + 75:5C). Separate test making instructions for the operational point of view of the teacher are written in the "MDT Book".

The primary MDT4 program reads student responses from a file generated by an optical mark reader (OMR), scores them according to the information marked on the control sheet and answer sheet, and then prints several reports. MDT4 consists of six individual programs called MDT4PGM1 through MDT4PGM6, as described below and shown in the sample output in Chapter Seven.

1. Program Documentation

PROGRAM	DESCRIPTION
MDT4PGM1	Grades the tape file and passes two files to the other programs: (1) The control file. (2) The graded file. No printed output is generated by this program.
MDT4PGM2	Uses the two files passed from program MDT4PGM1 to print the STUDENT RESPONSES REPORT. This report contains every response from every student along with all part scores and the total score.
MDT4PGM3	Uses the two files passed from program MDT4PGM1 to print the HISTOGRAM

	REPORTS. These are usually one-page reports for each part and one for the total. Each page contains a histogram of score frequencies along with the mean, variance and standard deviation. If a part or total has 101 to 200 points, a second page is printed.
MDT4PGM4	Uses the two files passed from program MDT4PGM1 plus an optional list file (code numbers and terms) to print the ITEM ANALYSIS report. This report specifies each unique response plus its frequencies and percentages for each question. The DIFFICULTY and VALIDITY REPORT is also printed by this program. The difficulty score is the percentage of responses that are correct; the validity is a measure of question reliability by comparing the answers of high scoring students vs. low scoring students.
MDT4PGM5	Uses the same two files from MDT4PGM1 to print the GRADE BOOK REPORT. This report is an alphabetized list containing: name, identification number, raw score, percent and raw scores for the parts.
MDT4PGM6	Uses the same two files to print the LIST FOR POSTING. This report is identical to the one of program MDT4PGM5 except the name is excluded and the list is in numerical order.
MDT4PGM7	Uses the same two files and the list file to print the INDIVIDUAL STUDENT REPORTS. These reports have the students' scores and total responses compared to the correct responses.

2. Installation Instructions

Only two files are needed to install MDT4 on a mainframe computer. The six programs of MDT4 are found in an "unloaded" PDS in file 1 on the installation tape. To "reload" the PDS use the following JCL, which brings the PDS back to a useable format.

```
    //A EXEC PGM=IEBCOPY,REGION=1024K
    //SYSPRINT DD  SYSOUT=$
    //SYSUT3   DD  UNIT=SYSDA,SPACE-(CYL,(5,1))
    //SYSUT4   DD  UNIT=SYSDA,SPACE=(CYL,(5,1))
    //SYSUT1                DD
DSN=MDT4.LOADLIB,DISP=OLD,UNIT=TAPE,
    //  VOL=SER=XXX999,LABEL=(1,SL)
    //SYSUT2                DD
DSN=RSCH.MDT4.LOADLIB,DISP=(NEW,CATLG),
    //  UNIT=3350,VOL=SER=DISK01,SPACE=(TRK,(40,,36))
    //SYSIN    DD  DUMMY
    //
```

File 2 on the installation tape (dsn=mdt4.jcl) contains the JCL needed to run the MDT4 programs. Note: This JCL needs to be modified with each actual run to identify both the input tape data set and, if used, the answer bank file with the code numbers and terms, as described below in Section 3.C.

3. Execution Instructions

When the MDT4 program is installed and operational, follow these instructions in order to grade an MDT test.

A. Scan the answer sheets with your OMR and copy the data into a disk file or a tape, using the sheet-scanning method appropriate for your computer center. Note the necessary order of the sheets:

1 control sheet (marking instructions are given below)
2 answer key
3+ student response sheets

The file's record format that the OMR scanner generated is:

column	contents
1- 9	unused ***
10- 13	number (1 to n) of sheet (written by sheet reader)
14- 24	unused ***
25- 33	identification number (SSN)

34- 53	name
54-203	responses to questions 1-50 (3 col. each)
204-278	responses to questions 51-125 (1 col. each)
279	sex
280	class
281	special codes 1-8
282	special codes A-E

B. Deliver the tape file to the computer room for mounting.

C. Change the JCL to run MDT4 as follows:

1. The FT08F001 on program MDT4PGM1 must match the input tape (or disk) data set.
2. If the teacher has provided a data file of the long list of terms and code numbers that the students used, update the FT10F001 of program MDT4PGM4 and MDT4PGM7 to match this data file. The data set containing the list must be of this format:
   col 2-4 -- the 3-digit number associated with the text
   col 5-80 -- the text associated with the 3-digit number
   (Although these columns are available, text is truncated on the right to twenty-one characters.)

D. Run the JCL stream to produce the printed output to be given to the teacher.

4. Marking of the Control Sheet

The technical staff should verify that each instructor provides a properly marked control sheet that preceeds the answer key and student response sheets. The control sheet is a normal F1 or D1 answer sheets marked in a specific way to specify the parts (subtotals) of the test and the point value for all questions in each part. Up to six parts are permitted for each side of the MDT F1 and D1 answer sheets. The three-digit section provides parts 301-306; the multiple-choice (single digit) section gives parts 101-106.

Notes: a. For each entry the number must be RIGHT justified in the three columns at each question position.

b. Information in question portions two

through six is needed only if composite (additive) scoring into a computerized grade book is available and if requested. Contact MDT Corporation for details about composite scoring.

Question position on sheet:	Meaning of what is encoded:
01	Labels requested (Blank=No; 001=yes)
02	(Opt.) Department number (three digits)
03	(Opt.) Course number (digits one-three before decimal point)
04	(Opt.) Course number (digits one-two after decimal point)
05	(Opt.) Section number (two digits)
06	(Opt.) Test number (two digits)
07	(not used)
08	Individual student reports (Blank = No; 001 = requested)
15	Number of questions in PART301
16	Point value for each question in PART301
. . .	
25	Number of questions in PART306
26	Point value for each question in PART306
27	Number of questions in PART101
28	Point value for each question in PART101
. . .	
37	Number of questions in PART106
38	Point value for each question in PART106
Name Block and Identification Number	Any message marked here (twenty letters, then nine numbers) will be printed in the appropriate header titles on the printout of reports.

Appendix 2

Thou Shalt Not Dupe

Either Way It's Wrong

People who would never walk into a store and shoplift a software product think nothing of making several copies of the same software. The results are the same. The act is just as wrong.

When it comes to unauthorized duplication of software, many people do not realize the costly impact on the software developer and the customer community. The relationship between customer and developer in a software transaction is one of mutual trust. The customer trusts that the developer has produced a product that will deliver the desired result, performs according to specifications, and is properly documented and supported. The developer trusts that the customer will make use of only those copies for which he has purchased a license, even though making additional unauthorized copies is relatively easy. Unauthorized duplication and use of software violates the U.S. Copyright Law, and unfairly deprives software developers of revenue they are entitled to receive for their work.

Software developers find that thousands of illegal copies have been made by customers who either innocently believe they are doing nothing wrong or simply choose to ignore the law.

The Law Is Clear

Reproducing computer software without authorization violates the U.S. Copyright Law. It is a Federal offense. The money paid for a software product represents a license fee for the use of one copy. It does not represent an authorization to copy. Civil damages for unauthorized software copying can be as much as $50,000 or more and criminal penalties include fines and imprisonment. Bills have been introduced in Congress to strengthen the law and increase penalties.

Myths and Facts of Software

Let's start by dispelling some myths with a few facts.

First, software developers *do not* condone unauthorized copying in order to gain market penetration.

Second, the price of software *does not* make unauthorized copying justifiable. The cost of a software product to a consumer represents only a small fraction of the publisher's development and marketing costs.

Third, although the cost of *softlifting* is borne initially by the software developer, it is paid for ultimately by legitimate users.

What It Means to You

It's obvious that legitimate software users are paying for theft along with software developers.

It's obvious, too, that no one is going to put up with it for long.

Think twice before you ask someone to give you an illegal copy of their software. Think three times before you offer to do it for someone else. *Softlifting or software piracy* is not only a crime; it's simply wrong.

Where to Get More Information

ADAPSO represents more than 750 corporate members that provide a wide spectrum of computer services and software including: micro, mini and mainframe software products; professional software services; batch and remote processing services; integrated hardware/software systems; education and training; and consulting.

For further information or questions on software protection, contact *ADAPSO at Suite 300, 1300 North 17th Street, Arlington, VA 22209*, or phone *(703) 522-5055.*

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Appendix 3

List of MDT Answer Banks
(February 1987)

Africa
- Countries, Capitals, Colonial Powers
- Terms and Concepts
- People
- Vegetation Zones, Drainage Systems, Terrain

Art Appreciation
- Terms and Concepts
- Artists
- Techniques
- Styles
- Movements (Modern)
- Artists (Modern)

Art Survey
- Artists
- Works
- Terms and Concepts

Classical Mythology
- Terms and Concepts
- Places
- Gods, Goddesses, Mythical Creatures
- People

Community Based Corrections
- Terms
- Places
- Person, Legal Cases, Acts
- Organizations, Programs

Criminal Justice (Intro)
- Terms and Concepts
- Amendments, Court Cases, Organizations, Places
- Names

Earth Science
- Terms and Concepts

Film Art
- Names, Terms and Concepts

Latin American Geography
- Geographic Places
  - Terrain and Regions
  - Water Features
  - Cities
- People and Organizations
  - People
  - Organizations and Events
- Minerals and Commodities
- Terms and Concepts

Maps and Map Reading
- Township and Range
- Scale
- Terms, Concepts, Map Symbols

Math
- Terms and Concepts
- Definitions and Postulates
- Theorems and Properties
- Greek Symbols

Spanish (Intro.)
- Nouns
- Verbs
- Endings
- Months
- Articles
- Phrases
- Composite (Listing of all the above)

Weather
- Terms and Concepts

World Geography

- Terms and Concepts
- Geographical Features
    - Water features
    - Terrain features
    - Cities
- Political Units and Macro-Regions
- Directions
- Climatic Types
- Composite (Listing of all the above)

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Index

Alphabetic codes: 123-124
Anderson, Paul S.: 4, 18, 21-28, 130-132, 141
Answer Banks: See Lists
Answer forms: 8, 23, 55-57, 134
  Cards: 56
  Costs: 155-156
  Manual scoring: 50, 51
  Prototype: 23, 24, 25, 30
  Sheets: 6, 16-17, 40, 55-57
Architecture: 124
Art appreciation: 31
Background: 21-23
Banks of Answers: See Lists
Banks of questions: 85-86
Blanks: 92
Bloom's taxonomy: 145, 165-166
Bulletin, MDT: 35, 50, 125
Calculations: (See Numerical responses)
Cards: (See Answer forms)
Chemistry: 12, 17, 86
Classroom conditions: 26,94-95
Coding (alternatives): 123-125
Cognitive: 18, 168-171, 173-175
Combined response areas: 124
Comments by
  Instructors: 29-33,37
  Originator: 37, 163
  Students: 3-4, 7, 26, 33-34
Commercial products: 35
Comparative research: 125-143
Competency-based testing: 145-146
Completion (See also Fill-in-the-blank)
Computers:
  Mainframe: 43, 44
  Micro: 44-45, 154
  Mini: 44
Consolidation effect: 128-130
Costs: 153-163
Criminal justice sciences: 31, 32
Curve: 97
Darkest mark discrimination: 23, 92, 95-96
Defintion of MDT: 15
Difficulty index: 126, 141-142
Discrete responses: 125
Distractors (See Foils)
Duchastel, Philippe: 128-130
"Dump": See Feedback, full listing
Educational issues:

115-169
  See also: Recall, Higher order learning
Educational Testing Service (ETS): 123
Elementary schools: 149-150
Entrance examinations: 147-149
Enhancements: 50
Errors in coding: 102, 104, 105
Essay (See also SA): 173-176
Feedback (Printout): 18, 47, 98-109, 160-162
  Full listing (dump) of student answers: 98, **99**, 100
  Histogram: 100, **101**
  Indices of difficulty and discrimination: 100, **101**
  Individual student reports: 105, **106**, 107
  Item Analysis: 102, **103**
  Listing of grades: 107, **108**, 109
  Statistics (descriptive basic): 100
  Subtotals (parts): 86-87, 89
  Word responses: 102, **103**, 105, **106**
Fill-in-the-blank questions: 7, 8, 18, 33, 120-121, 125-140, 153-163
Financial: (See costs)
Five-choice (5-choice) questions: (See Multiple choice)
Foils (Distractors): 10, 11, 18, 84-85
Formative: 117
Free response (See also Recall): 123
Gay, Lorraine: 127-128
Geography: 4, 5, 8, 11, 22, 23, 24, 135
Grade book: 18, 47, 50, 109, **110**, **111**
Guessing (See also Recognition; Recall): 4, 7, 94, 117-118
Hardware: 18, 19, 23, 43-46
Higher order learning: 165-177
History: **9**, 10, 12, 14, 15, 30, 141-142
Hole punch (manual scoring): 50, 52, 53
Home economics: 29
Introduction to
  Readers: 1-19
  Students: 91-94
Item Analysis (See also feedback): 47, 102, **103**
Illogical responses: 104
Instant scoring: 112, 113
Job training: 151-152
Junior high/middle schools: 150
Kanzler, Eileen: 141
Keylist: 123, 125-127
Know: 3, 7, 8, 94
Levels of education: 19
List Maker: 30, 49, 58-59
Lists: 15, 22, 27, 40, 56-72, 92-94, **133**
  Alphabetizing: 67
  Ambiguous answers: 67-68
  Answer banks: 172
  Capital letters: 65
  Copy quality: 69, **70,71**
  Costs: 156
  Examples: 5, 9

  Final preparation: 69, 72
  Inherent order: 67
  Manual preparation: 58
  Modifiers: 11, 93
  Number of terms: 62-63
  Numbering the terms: 63-64
  Plastic page protectors: 67
  Plurals: 93
  Preparation procedures: 59-62
  Preprinted: 58
  Prototype: 23-24, 27
  Reversal of key words: 93
  Short lists: 83
  Versions: 66, 93-94
  (See also List Maker)
Manual scoring: 50-53,
Map (Supplementary page): 11, 13
Mastery learning: 145-152
Matching: 119, 121-122
Mathematics: 32-33
Measurement levels: 172
Media coverage: 34, 36
Medical education: 75,
Meyer, George: 127
Microcomputers: See computers
Military: 32, (See also training)
Modifiers: 11, 93
Multiple choice: 3, 10, 11, 19, 21, 22, 118-119, 125-143, 170-172
Music: 29, 77
None of the above (No reasonable answer is on this list): 8, 92
Numbering the terms: See lists
Numbers, reserved: 63-64
Numerical responses (not code numbers): 11, 32-33, 64-65, 66, 82
Objective tests: See True/False, Multiple-choice, Matching
Optical Mark Readers (OMR): 40, 45-46, 154-155
Part scores: See Subtotals
Pioneer Users: 29-33
Plastic page protectors: 67
Practice effect: 129, 170
Printout: See Feedback
Professional qualifications: 146-147
Programs: See Software
Question writing: 79-86, 158
Recall (free-response): 120, 166
Recognition: 121
Reliability index: 126
Reports: See Feedback
Research: 18, 30, 117-143, 162-163, 179-180
Retention: 128-130, 132-143
Rigor: 122
SA (Short Answer): 14, 15, 16, 17, 18, 22, 56, 109, 112
Sax and Collet: 127-128
Scanners: (See Optical mark readers)
Scores: 87, 89, 97
Scoring: 97-98
Secondary schools: 129, 141-142, 150-151
Short Answer: See SA
Software: 40, 46-50, 155
  Mainframe: 47-48
  List Maker: 49

  Grade book: 50
Space for seating and writing: 94-95
Standardized tests: 125-127
Stem: 10
Student instructions: 91-94
Subtotals: 47, 86-87, 89
  Noncontiguous: 87, 89
Summative: 117
Supplementary pages: 11, 13, 73, 74, 75, 76, 77, 83-84
System: 39, 40, 41, 161
Test making:
  Definition questions: 82
  Demonstration questions: 8-15
  Limitations: 80
  Multiple choice: 81-82
  Number of questions: 79-80
  Numeric responses: 82
  Short list questions: 83
  Software: 50, 86
  Supplementary pages: 83-84
  True/false: 81
Test scoring: 47
  Range of scores: 79-80
Time: 142, 149, 156-163
Training: 145-152
Tricks: 118
True/false: 81, 117-118
University (Examples throughout book): specific reference: 146, 152
Upgrades: See Enhancements
Verbal/Vocabulary: 125-127
Vernon, Walter: 121-122
Ward, William: 123, 125-127
Word responses: 47, 102, 103, 105, 106
Writing (See Essays and SA questions)
Zero: 92

About the Author

(Written by James S. Schoner)

Perhaps Paul S. Anderson is best described by noting the complimentary perceptions of students, colleagues, and individuals who work with him. They see a dedicated educator, talented innovator, vibrant researcher, and consistent friend. The words are not mere captions; they are spirited qualities of a rare individual.

Paul S. Anderson, Ph.D., is an Associate Professor of Geography at Illinois State University, Normal, Illinois. His education includes studies as a Fulbright-Hayes scholar, with degrees from Augustana College, the University of California at Berkeley, and the Australian National University.

He is the principal author of two textbooks, fifty academic papers/publications, an essay on world peace, a movie script, and a book on dieting. In addition, he holds a patent for a residential recreation facility, and, as told in Chapter Two, he is the creator of the MDT method.

Dr. Anderson's activities reveal a striking diversity in his talents. His ability to perceive and utilize new opportunities along well-worn paths is expressed in his personal logo: The Upright Egg.

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